1s. 1s.

THE

Uses of Animals

IN RELATION TO THE

Industry of Man.

Silk.
Wool.
Leather.

Bone.
Soap.
Waste.

BY

E. LANKESTER, M.D., F.R.S.

LONDON:
ROBERT HARDWICKE, 192, PICCADILLY.

USES OF ANIMALS.

THE

USES OF ANIMALS

IN RELATION TO THE

INDUSTRY OF MAN:

BEING A COURSE OF

LECTURES DELIVERED AT THE SOUTH KENSINGTON MUSEUM.

BY

E. LANKESTER, M.D., F.R.S.

SUPERINTENDENT OF THE ANIMAL PRODUCT AND FOOD COLLECTIONS.

First Course.

LONDON:

ROBERT HARDWICKE, 192, PICCADILLY.

1860.

PREFACE.

The following Lectures were delivered, by permission of the Committee of Council on Education, in the lecture-theatre of the South Kensington Museum. They were undertaken for the purpose of explaining, to those interested on the subject, the nature and objects of those animal products which are employed in the uses of daily life, a collection of which exists in the Museum.

As notices of the lectures delivered in the Museum had appeared in the newspapers, and I was anxious that they should come before the public as correct as possible, I complied with the request of the publisher to correct the notes of the short-hand writer, and they must now be rather regarded as reports of lectures delivered extemporaneously, than as lectures written for the press. They were delivered to popular audiences, and their object was more to excite interest and lead to inquiry than in any manner to treat the respective subjects exhaustively.

E. L.

CONTENTS.

ON SILK:—

Nature and object of the Course of Lectures—Distinction between Animal and Vegetable Manufactures—Useful Products of Animals belonging to the Invertebrate Groups—Silk and its Manufactures—Insect Dyes.

ON WOOL:—

Nature of the Epidermal System in the Animal System—Physical and Chemical Nature of Wool—Sources of Wool—Woollen Manufactures—Worsted Manufactures—Alpaca and Mohair Manufactures—Uses of other kinds of Hair.

ON LEATHER:—

Nature of the Skins of Animals—Process of Tanning—Sources of Tannic Acid—Skins employed in Tanning—Preparation of Skins—Leathers not prepared by Tanning—Applications of Leather—Manufacture of Parchment and Vellum—Manufacture of Glue.

ON BONE:—

Nature of the Skeleton of Vertebrate Animals—Microscopic Structure of Bone—Chemical composition of Bone—Uses of Bone—Nature of Ivory—Structure of Teeth—Animals producing Ivory—Applications of Ivory.

ON SOAP:—

Nature of the Adipose Tissue of Animals—Microscopic Structure of Fat—Chemical Composition of Fat—Manufacture of Soap—Soluble, Soda, or Hard Soaps—Soft, or Potash Soaps—Insoluble Soap, Lime Soap, Lead Soap, or Diachylon Plaster—Process of Soapmaking—Manufacture of Candles.

ON WASTE:—

Application of the Physical Properties of Waste—Silk Waste—Woollen Waste—Leather Waste—Bone Waste—Application of Chemical Qualities of Waste—Illustration of Uses of Waste in the Value of a Dead Horse.

Fig. 1.

ON SILK.

In pursuance of an object that I had in view in delivering a course of Lectures on Food, I now purpose delivering a short course of Lectures on Animal Products used in the Arts and Manufactures. Most people are, perhaps, acquainted with the fact, that the Kensington Museum is a representative of two great departments which the Government maintains for the purpose of educating the great masses of the people of this country. It is called the Science and Art Department.

With the Art Department I have little or nothing to do, and would merely here commend it to your

earnest attention, and speak of it in terms of equal praise with the Department of Science, to which I am more immediately attached.

Standing between our Art Museum and our Science Museum, there is an additional Museum, which has more particularly in view the teaching of the various branches of elementary knowledge which are brought before the young. It is, then, to the Science Collection that I wish more particularly to call your attention; and I would just say, in order that you may understand the position in which this collection stands in relation to other collections, that it is only one part of a great whole. We bring together Museums of Natural objects, as distinguished from objects of Art, with which man's hand and mind have had so much to do. With regard to these natural objects, they may be arranged in a variety of ways. There is, first, the Natural History Collection, in which are arranged the varied forms of minerals, plants, and animals. Such a collection is the British Museum, the intention of which is, to illustrate the varied forms of created objects which are found in the external world; but in the Museum at South Kensington, there is no attempt to illustrate so extensive a subject; but the object there kept in view is, the illustration of the particular uses of minerals, of plants, and of animals; and within the last few years, there has arisen in this country and other countries of Europe, a series of Museums to illustrate the uses of external objects to man. It has been found that man's advancement upon the earth is entirely due to the way in which

he uses these things; not so much to his exhaustive knowledge of the properties of natural objects as to his knowledge of particular facts, so as to apply them to his own wants. Hence we have Economic, or Trade Museums, representing first the raw materials of the mineral, vegetable, and animal kingdoms; and then representing them in the various processes of their manufacture.

The Governments of Europe have, more or less, recognized the importance of these Museums. Our own Government has been amongst the foremost in this respect. Thus, we have in Jermyn Street a Museum which not only contemplates the Geological History of Great Britain, but which also exhibits the various objects of the Mineral Kingdom used in the arts and manufactures. Thus, the materials used in the formation of pottery, of metallic works, and of bricks and other building substances, are represented there. Then there are the great Botanical Gardens at Kew, where we find not only living plants, but a great collection of the raw materials of plants used by man in the arts and manufactures: there also, to some extent, is an attempt to represent the manufacturing processes of vegetable substances. Then, in this institution we have the Animal Kingdom treated in the same way. We have a great collection of animal products which are used in the arts, and we have also examples of the various processes which the raw material undergoes before it becomes fit for the use of man.

In these Lectures I shall endeavour to show you what is the nature of the animal substances thus exhibited, and what are the processes through which they pass

in order to be used by man in the various purposes of life. But there is another view of the external world to which I would draw your attention. The external world supplies man with things which are not merely used by him to supply his artificial wants—such as clothes, houses, plates, teacups, and other things,—but it also supplies him with materials which he needs in common with the whole animal kingdom. There is the salt in the water, and the various other saline substances which we eat, from the Mineral Kingdom, for the supply of our natural wants. Then there are the productions of the Vegetable Kingdom—potatoes, cabbages, wheat, rye, and other substances used as food. Then we take the animal, we roast him and eat him; and in this way the Animal Kingdom supplies our natural wants.

I want you to see this parallelism:—On the one hand, Nature supplies us with the food which we take from day to day—and this is illustrated in our Food Collection; on the other hand, man is an artificial animal, dressing and using a variety of things, sometimes from the Mineral or Vegetable, and sometimes from the Animal Kingdom; and it is to the class of substances supplied by the latter for this purpose that I wish to draw your attention in this and the ensuing Lectures.

It is just as man gets to know the properties of natural products that he uses them, for his benefit, and becomes civilized by his use of them. I do not know that I can illustrate this use of the Animal Kingdom better than in things familiar to all of us. Who would think that the little cocoons

of the silkworm could ever be manufactured by man's ingenuity into the most highly-prized articles of dress, which have at all times distinguished the monarch and the senator from the common people, giving a more pleasing and sightly appearance to the human form than perhaps any other substance? Thousands of our fellow countrymen and fellow country-women are employed upon, and depend entirely upon the employment derived from these little cocoons. Who would have thought that all this depended, from the earliest times, upon the knowledge of the way to unwind the silk, to spin it, and to weave it? And then, having done all this, by his knowledge man is enabled to take a variety of substances from the mineral, from the vegetable, and from the animal kingdoms, and to stain the woven silk, giving it a variety of colours; and whilst he thus increases the beauty of the articles, he increases the desire and the demand for them. Just as man's intellect is employed in this occupation, so does it seem capable of expanding and obtaining higher results; so that we may say that just as the intelligence of man exhibits itself in various manufactured articles, so does his civilization become developed. When you go into a community of well-dressed, well-cared-for people, you know they are civilized. And upon what does that depend? It is not the ignorant man that is civilized—it is not the lazy man that is civilized: civilization can only occur in an intelligent, in an active and industrious community. I want you, then, to study a little more systematically the scientific principles on which the arts and manufactures employing animal substances

depend. I wish we had more systematic teaching of this kind than we have, and that it had fallen into abler hands to deliver this course of Lectures.

Now, before proceeding any further, I would just draw your attention to the distinction between animal and vegetable substances, on which much of the difference between animal and vegetable manufactures depends. I would first refer to the fact that the two sets of bodies are composed of different materials, and those materials are represented by those great primary compounds out of which, to a greater or less extent, plants and animals are naturally manufactured. Thus, taking plants, whether they are composed of vessels or of cells, such as those represented in this drawing (Fig. 2), we shall find that they are composed of a hard substance, which the chemists call *cellulose,* and which is ordinarily called *wood,* when it is formed into the trunks and branches of trees. Now when we deal with the Vegetable Kingdom in our manufactures, we use this cellulose; when we cut down timber-trees, and saw them into boards, or when we take those delicate fibres for handkerchiefs, muslin dresses, and things of that sort, we deal with cellulose. But let us look again at these cells and fibres, when they have been worn—there is none of them wasted. After we have worn all our cotton and our linen to rags, the rag-collector picks them up for the purposes of the paper-maker. This cellulose, then, is converted into paper. Cellulose, however, exists naturally in the

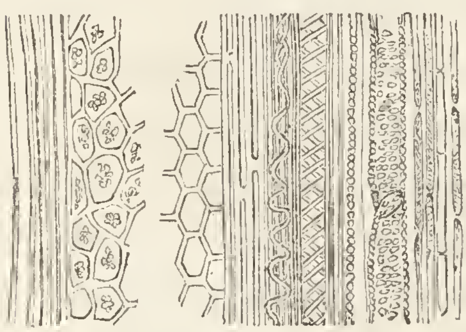


Fig. 2.

world,—in the forests of Asia, Africa, and America, and there is plenty in our own wildernesses; and it is only a question of whether a man shall wear it first upon his back, or have it manufactured into paper at once. I believe the abolition of the paper duty would give the greatest incentive to young chemists and manufacturers to pursue the study of this subject, and to make such discoveries and improvements in the art of paper-making, that the paper-manufacturer might snap his fingers at rags, because of the abundance of available cellulose in the vegetable kingdom.

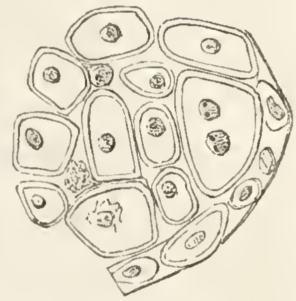


Fig. 3.

Now, when we examine the animal kingdom, we do not find any cellulose,—at least, not worth the attention of the manufacturer. Silkworms do not form it, nor does it exist in the horns of cattle, nor in the hairs of animals, nor the feathers of birds, nor in any of the animal products which we use in the manufactures; but we do find another thing, which is called *gelatine,* or the substance which we use in making glue, sizes, jelly, and the like: it always assumes the form of cells, but never has the properties of cellulose. The walls of the animal cells represented in Figs. 3, 4, and 5, are gelatine. Gelatine is soluble in hot water, while cellulose is not. A leg of mutton will boil to rags, but the leg of a table is insoluble in hot water.

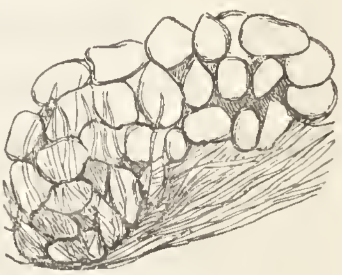


Fig. 4.

Fig. 5.

Gelatine is known by its specific gravity being greater than cellulose. Animal substances sink in water, but vegetable substances swim. Cellulose conducts heat with greater facility than gelatine: thus we are warmer in animal than vegetable clothing. Animal substances are stronger. These, then, are some of the distinguishing features between substances that are manufactured from the vegetable kingdom, and substances which are manufactured from the animal kingdom. But you must not suppose that all animal substances are composed of a soluble gelatine. The horns, hairs, and hoofs of animals, for example, are not soluble in hot water. I shall examine the chemical composition of animal products more minutely when I come to speak of them. The artisan—the person who is working in these things—will do well to remember these facts, because out of some of them come important conclusions. Some dyes, for instance, which are absorbed by the animal tissue, will not be taken up by the vegetable fabric. The dyes of cotton are not the dyes of wool or silk; and thus out of these considerations arise general facts with regard to working in animal and vegetable substances.

I might detain you longer on generalities, but I will at once proceed to the particular subjects of my Lecture. I do not pretend to be a manufacturer, or acquainted with all manufacturing processes, but I do hope to be able to point out to you the advantages of studying the chemistry and natural history of the materials which you buy, sell, use, or manufacture. Now, looking at the animal kingdom as a whole, we see, in the first place, it supplies man with

food; but we have nothing to do with that upon the present occasion. We also use the vital force of animals, in our civilized life, as beasts of draught and burden. This is a kind of power which we constantly employ in horses, more especially in this country; but the elephant, the camel, the ox, and a variety of animals, are used in this way. I draw attention to this, but it is not what I want to treat of here; what I want more particularly to speak of here, is the way in which their products or parts are applied to the use of man. Take silk. Well, silk is woven into garments; it is woven in a variety of ways, and used for the purposes of textile fabrics. We have also other uses to which animal substances are applied: just as we use the solid portions of minerals and plants, so we use the solid portions of animals. There are, for instance, the bones, the horn, the hoof, the teeth, and a great many other parts, which are used by the manufacturers of solid materials of various kinds. Then again, we find that the chemistry of the animal is of a more complicated kind than the chemistry of the vegetable; and we obtain from animal substances compounds we cannot get from vegetable and mineral substances. We know that man is but a poor chemist in his laboratory, as compared with a plant. Take a spire of wheat, expose it to the action of carbonic acid gas and ammonia,—the little plant takes up those elements in the most marvellous way, and converts them to its own use in its wonderful laboratory; and, lo! there is the cellulose, the oil, the starch, the sugar, the albumen, and fibrine; and those little plants are doing this in every

moment of their existence, for the use of man and the animal kingdom. Thus the vegetable exercises an influence on the animal kingdom; and the animal takes up the starch and the sugar, the oil, the albumen, and the fibrine out of the plants, especially the latter, and they loosen and change their chemical affinities. An animal is more easily decomposed than a vegetable. If you doubt that, place a log of wood and a dog in a stagnant pool: the dog, in a very few days, will become in such a state that you would not like to come near him, while the wood may lie for years before it becomes decomposed. We intercept, then, as it were, the elements of animal bodies while they are undergoing these changes. There are skins: we throw tannic acid on them during their change, and they become leather; and there is the fatty matter, of which we make soap: we catch hold of these substances while the chemical change is going on in them, and we employ them and turn them to a hundred uses in the arts of life. Then there are certain things in the animal kingdom which come to us as disagreeable odours—such as the muscovy cat, with its stinking scent; yet this animal is caught, and we import for our perfumes 10,000 ounces every year of that civet which we dislike so much. Again, there is the musk from the musk-antelope, ambergris from the whale, and castor from the beaver, all of which are used as perfumes. Then there are dyes: cochineal insects and lac insects yielding the beautiful colours with which we dye our silks. Lastly, there are certain waste materials from animal manufactures, such as the waste of the silk and woollen manufactories, the refuse of bone manufactures, the offal of slaughter-houses,

and the refuse of our large towns; these can all be used; and when these things are studied, we find they are not refuse. When we come to consider these things, we shall find that God has made no waste in the world at all. There is a maxim, "Waste not, want not;" and we have wasted, and do waste; and I shall call attention to this waste in many things, and show that many branches of industry have sprung up from the utilization of this waste.

I begin with Silk, because it is an instance of the use man makes of the lower, or invertebrate animals. You will see, if you look at the whole animal kingdom, how very few conquests man has made among the lower animals. Nevertheless, among the lower animals, those that have no backbones, there are many of great service to man. Sponge is the skeleton of an animal belonging to the invertebrate group. There are a variety of shell-fish yielding us mother-of-pearl, cameos, and other objects of ornament. Then we come to the various forms of articulate animals, to which the insects, the crabs, and the lobsters belong. There are many useful products among these: there is the bee, yielding honey; the blistering fly, with its secretion so valuable to man in disease; and the leech, with his useful blood-sucking propensity. But I cannot at present say of these animals as I can of the higher class, that every part of them is useful: for instance, there is the horse, you can use every part of him; of his skin you can make leather, or you may boil him down and make him into jelly, or you may eat him; but no portion of him ought to be lost. It is, however, the insect tribe to which I wish

to draw your attention more particularly, in order to bring before you the material of one of the largest branches of our manufactures; namely, Silk.

Many insects undergo changes of a remarkable kind: there are some that change partly, and some that undergo no change at all. Some lay eggs, which produce creatures very much like their parents, while others produce creatures more or less like their parents; and others, again, produce creatures which are utterly unlike their parents. Take, for instance, the group to which the common moths and butterflies belong: these lay eggs, from which come larvæ that become insects unlike their parents, and which spin for themselves cocoons,—a sort of tomb,—and pass into things called chrysalides, in which state they lie for weeks, months, and sometimes even years; but at last the chrysalis bursts, and out comes the perfect insect—the butterfly or moth. And it is to these families that our silkworm belongs,—to a family known to naturalists as the family of *Bombycidæ*. To this family also belongs the *Saturnia Atlas*, which is the largest insect known, measuring eight, and sometimes nine, inches across its wings. Then, this family produces caterpillars, which form cocoons, or nests, composed of silken fibres, known by the name of silk. It is not, however, every species of this family of *Bombycidæ* from which we can obtain silk, although there are a number of them that yield a silken fibre just in the same way as our common silkworm. In the Museum there are a large number of specimens of silk obtained from other species of moths besides our common silkworm moth. That is an important

point to recollect. Circumstances may supply us with means by which we may obtain as large a supply from some other species as we do now from the common silkworm. There are difficulties in cultivating the common silkworm moth; and if we could find a hardier kind of moth for this purpose, it would be a great benefit. The more knowledge we have of these creatures, the more likely we are to discover and introduce new sorts and kinds, and thus increase this serviceable produce. It has not been by ignorance or accident that man has discovered the use of any of these things; but just as he has searched into nature, so has he been rewarded by discoveries; and in every step discovery upon discovery has been made, by intelligent men. If we expect to progress, we must cultivate our minds more and more, and bring them to bear on the practical arts of life.

The following is from the catalogue of the South Kensington Museum:—

"The Bombycidæ include the largest of all the moths yet known, the *Saturnia Atlas,* the extent of whose wings measures between eight and nine inches. The ground colour is a fine deep orange-brown, and in the middle of each wing is a large sub-triangular transparent spot: each of these transparent parts is succeeded by a black border, and across all the wings run lighter and darker bars, exhibiting a very fine assortment of varying shades. The upper wings are slightly curved downwards at their tips, and the lower wings are edged with a border of black spots on a pale buff-coloured ground. The antennæ are widely pectinated with a quadruple series of fibres, which have a very elegant appearance. This moth is met with in Southern India, and the Chinese tussah silk has been said to be obtained from it.

"Among the various moths found in Assam, and other parts of India which produce silk, are the *Bombyx Mori;* the tussah (*Saturnia paphia*); the eria, or arindy (*Bombyx Cynthia,* or *Phalæna*

Cynthia); the moonga (*Saturnia Assamensis* of Helfer), the joree (*Bombyx religiosa*, Helfer); and the *Saturnia Silhetica*, Helfer.

"Another speeies of *Saturnia* (*S. Selene*), the posterior wings of which are prolonged into a tail-like proeess, is common in southern India. Its ehrysalis is enveloped in a silky eovering, so like that of *S. paphia*, that it would probably be found to yield a strong and useful thread.

"The eossimbazar produces a large cocoon; but this worm will only produce silk annually.

"Desse is the small indigenous or native silkworm of Bengal, which may be produeed nearly throughout the year. It yields silk of a bright yellow eolour. The eggs are hatehed and formed into coeoons in from fifty-five to sixty days in the November and Mareh *bunds*, or seasons; from forty to forty-five days in the Oetober; and from twenty-eight to thirty days in the April and June *bunds*.

"The nistry tribe of silkworms eomprises three speeies — the madrassie, the soonamooky, and eramee. The soonamooky are the best: like the madrassie, they are very hardy, requiring little eare, and not being at all choice in their food.

"The madrassie or foreign eoeoons rank next. They produee silk of a greenish hue, mueh inferior to the desse or soonamooky, but the produee is large. The worm is distinguished from the desse by a blaek mark under the throat.

"The tussah silk-worms are reared in all the western forests, and there are three different kinds of the 'goottees,' or eocoons, eollected in September; namely, the moonga, the most common, whieh produee a coarse thread, easily wound; the teerah, a smaller eocoon, with a firm thread, but not so easily wound, nor so mueh valued by the weavers; and the bonbunda, the largest of the wild silkworms: the thread being eoarser, runs easier, and is, therefore, in more estimation by the weavers."

Now, some of these silkworm moths assume very splendid forms; we cannot, however, greatly admire the little moth to which we are so much indebted, — the *Bombyx Mori* (Fig. 1), which produces all this silk, and gives employment to a hundred thousand people in this eountry, and to millions in other parts of the world. In the drawing of our moth, you see it has dark marks on its wings.

Now, this moth deposits its eggs in the autumn of the year; it is hatched from the chrysalis in the cocoon, and the eggs, which are deposited in the latter end of the summer, will hatch the next spring. After they are hatched they form little worms, larvæ, or caterpillars, and many of you may have seen them, and perhaps kept them: they may be seen any day in May, in Covent Garden market; they go on for six or eight weeks in this condition, increasing in size, and as they increase in size they eat more and more, until at last we find them an exceedingly rapacious crew, devouring large quantities of the leaves upon which they live. They are at least two inches long before they spin their cocoons. During their growth they shed their skins, sometimes four and sometimes five times, before beginning to make their cocoons. By this process the creature is enabled to increase in size. This is the natural habit of moulting. Birds throw off their feathers at certain seasons; horses throw off their hairs; and so human beings are constantly moulting; for if you take a brush and brush your skin, a certain quantity of the epidermis will be brushed away. From day to day, from year to year, we moult our skin, and thus we throw off that matter which is no longer of use to us. This moth is called the *Bombyx Mori*, because it feeds on the mulberry. The *Morus nigra* is the species of mulberry that has been cultivated in Great Britain. Unfortunately for us, the silkworm always chooses to be hatched just before the time the leaves of the mulberry-tree come out, so that we have a difficulty in feeding them. It does not seem that we have

been able here, nor anywhere else, to retard their hatching. On this account we have had recourse to feeding them upon other substances. The mulberry-tree yields a milky juice, and we, taking the hint, substitute the lettuce and the dandelion, which both yield a similar juice, and the creatures will rather feed on these than die; but it is a fact that silkworms fed in their early condition on lettuce-leaves, never thrive like those always fed upon mulberry-leaves. Various attempts have been made to cultivate the silkworm in Great Britain. The black mulberry was early introduced, after the successful culture of silkworms on the Continent, and there are large orchards remaining which were planted at that time; but all attempts have failed to make the rearing of silkworms a paying speculation. Sometimes the young silkworms and the leaves will come out together, at another time the mulberry will persist in coming out a month later, and thus the cultivation in this country has been abandoned. At the same time, there is reason to believe that it might thrive in this country, as it succeeds in Russia and various parts of North America, and silk has been recently produced in Great Britain: but the question is, how can we obtain silk from our worms permanently, without any of that liability to the failure which has so frequently attended the attempts at cultivating silkworms in this country?

Now, I recollect that at various meetings of the British Association, a lady appeared from time to time, bringing specimens of silkworms and manufactured silk, endeavouring to show the members of the Association that it was possible to produce silk here; and I

recollect a very splendid piece of silk was produced, which was presented to Her Majesty by Mrs. Whitby, of Newlands, the lady to whom I have alluded. But how did she effect this? Why, instead of cultivating the old black mulberry, she cultivated another species — the *Morus multicaulis* (Fig. 6), having a leaf and fruit somewhat of a different kind, and not so eatable as the common mulberry; and she found this species produce leaves much earlier than the *Morus nigra*,

Fig. 6.

and on this account she succeeded from year to year in producing good crops of silk of the best quality. From her experience, therefore, we may conclude that silk may be cultivated in this country; and I do, therefore, most earnestly recommend the subject to the study of those who are anxious to increase the means of employing our agricultural poor. There is no question that the time of females and children may be most profitably employed in attending silkworms, where they have nothing better to do. In the South of Europe the silkworm is fed on the *Morus alba* (Fig. 7), but it is too delicate to bear leaves early enough for the silkworms in this country. There is one great drawback to the culture

Fig. 7.

of silkworms, and that is, the disease to which they are subject, which is called muscardine.

Those who are at all engaged in the manufacture of silk, in the sale of silk, or in the purchase of silk, well know how it has varied in price, and how much the markets of Europe have been affected by the prevalence of this disease. It has destroyed large numbers of the European worms within the last four or five years. Now, this disease is of a kind that sometimes affects the human body. The human hair is occasionally affected by a fungus, which produces disease. This fungus attacks the body of the silkworm, and so entirely destroys the creature, that when the time comes for it to form its cocoon, it is utterly unable, and the result is, a failure of the crop. Here is a drawing of a diseased worm and the fungus which attacks it. (Figs. 8, 9, 10.)

Fig. 8.

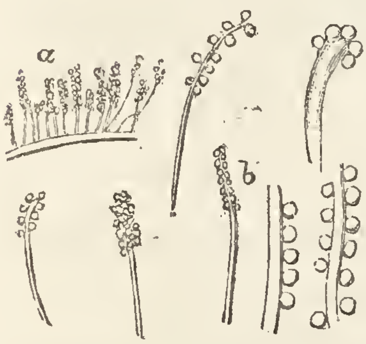


Fig. 9.

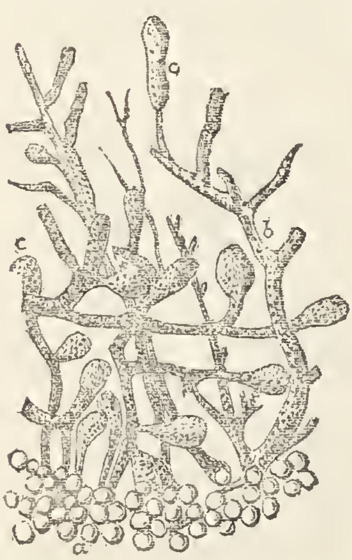


Fig. 10.

It has been lately found, in France, that feeding them with sugar prevents the disease; but it further appears that it is a disease of overcrowding, such as arises in our courts, alleys, and close streets, where we want to occupy as little ground as possible. People who cultivate silkworms crowd them together in close places, without a proper supply of pure and fresh air; and it has been ascertained that when a large supply of

fresh air has been admitted to the cases in which they have been kept, the disease has disappeared. There is no doubt that the disease will spread from establishment to establishment, which shows that the same laws which prevail in the life of man apply to the life of the lower animals.

Now, there are several sorts of silkworms; just as we find among human beings that there are small ones and large ones, black ones, brown ones, and white ones, so we find among these creatures a great variety. In France there is the *Sina* variety, which produces white silk and a small cocoon; and there is the *Syrie,* which produces a large cocoon; then there is the *Novi,* which makes the small, fine cocoon, producing a yellowish but very lustrous silk.

The *Bombyx Mori* is not found in our fields or hedges, although occasionally a few eggs may fly out of windows and get into our hedges and produce their cocoons; but there is something in our climate which will not allow them to thrive. The year 1858 was an exceedingly favourable summer for the production of these creatures in the open air, and a communication was made at the meeting of the British Association at Leeds, by a gentleman who had seen them feed and form their cocoons on a hedge in the open air. The silkworm is a native originally of China. Whilst our forefathers were naked savages, understanding nothing at all about clothing, a large proportion of the population of China were clothed in silk. There is a lesson! You see they have not been a people of progress: they are almost a stereotyped edition of the human race. There they

were 2,000 years ago, walking in silks, and there they are now, without advancing; for they have neglected the culture of natural science, whilst we, who have cultivated it, are gradually progressing. They have had no Bacon to point out the way to investigate the properties of matter, or the importance of regarding man as the minister and interpreter of the laws of nature: they pursue the business of life as an art, and know nothing of science. If you want to progress or maintain your position, you must go on increasing your knowledge of the external world. There are other countries in Europe who are now treading on your heels, and if you do not go forward, you will be left behind; in which case you may become another illustration of the want of progress of which the Chinese are so lamentable an example.

From China the culture of silk seems first to have been introduced into Hindostan, and then into Europe, in the reign of the Emperor Justinian. The silkworm is said to have been introduced into Constantinople by two Nestorian monks, who were promised a reward if they would secure the worms which produced the silk. This they did, by secreting the eggs in hollow canes. The ancient Greeks knew something of silk, and the Romans wore it as an article of luxury; but none of them knew anything of its history. Aristotle thought it must have been produced by some worm like a caterpillar, others thought it the produce of plants; and a Roman poet refers to it as secreted by flowers. In the sixth, seventh, eighth, and ninth centuries, the culture of silk in Europe was confined to the Greeks of the Lower Empire. In the thirteenth century it was

introduced into Sardinia, where it found a home. In the fifteenth century it was introduced into France. In the sixteenth century it was introduced into England, but failed as an article of trade. We find James the First, when the English ambassador went down to Scotland to congratulate him, writing to the Earl of Marr, to beg of him to lend him a pair of silken hose, so that his sovereign might not "appear as a scrub before strangers." But throughout all Europe silk was, until a very recent period, an article of excessive value. Nor had the manufacture of silk in England up to the seventeenth century been more successful than its growth. Most of you know of the revocation of the Edict of Nantes. This intolerant act, which drove half a million of people from their homes, threw on to our shores 50,000 intelligent Frenchmen, who, many thanks to them, laid the foundations of the great silk-manufactories of this country. This great branch of industry was to rise and rise, and never go back—always to increase. Although we could not rear the silkworm, we were able to manufacture the silk, and now we have a great trade in silk. In 1820 our exports were valued at £371,000; in 1856 they had reached £3,000,000. The average imports of silk in 1856, 1857, and 1858, were worth £7,000,000. We have at this moment 300 silk-manufactories, with two millions of spindles going, and steam machinery of 4,000 horse-power; independently of the hand-weaving of Spitalfields, we have 15,000 men and 35,000 women employed in the manufacture. It is supposed that all those engaged in the production, manufacture, and sale of English silks, do not number much less than a

million of persons. Some curious calculations have been made with regard to the quantity of silk manufactured in the city of Lyons. It is stated that the silk consumed in the year 1840 was 2,205,000 lbs.; and that it was produced by four thousand millions of cocoons. The fibre of one cocoon measures 1,526 feet in length; so all the silk fibre consumed in one year in Lyons, would measure six billions, five hundred thousand millions of feet; which is a quantity enough to wind fifty-two thousand times round the circumference of the earth. So much for the manufacture of one town alone; and, of course, our manufacture is much larger than that.

Now let us look at the way in which the silkworm performs its share of the work. After the creature has cast its skin five or six times, it begins to form its cocoon, which is very much shorter than itself. We may well wonder how it can do this; but if we watch it, we find that it is done by fixing the hinder part of its body, and then by raising the forepart, which is very flexible, giving facility for reaching its tail, and thus covering itself all over with the web. By this means the hardened case is formed, which we call the cocoon.

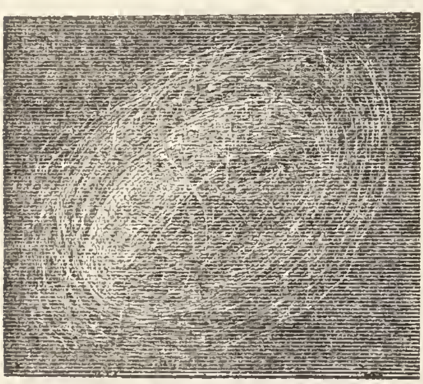


Fig. 11.

The way in which the silk for the web is formed is very curious. Let me here draw your attention to the interior of the animal, in which are two large glands, one on each side of the body of the silkworm; and it is in these glands that the material of the silk is

secreted (Fig. 12). These glands end in ducts, which terminate in an organ called a spinnaret (Fig. 13); and on each side of the spinnaret are two little glands, which produce a sticky matter, very much like the silk itself, by which the produce of the two larger glands is made to adhere together and produce one fibre. This substance, when placed under the microscope, is found to have a very simple structure (Fig. 14). It is transparent, and composed of a material called *sericin* by chemists. The silken fibre has great strength, and, perhaps, is the strongest of all organic fibres, in proportion to its size. The value of silk, then, depends mainly on its strength and fineness.

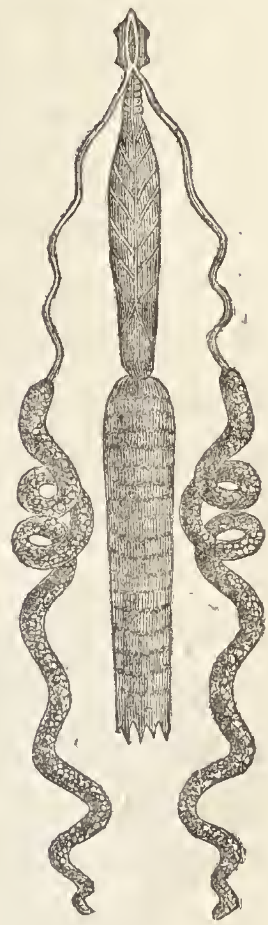


Fig. 12.

Silk is obtained by the English manufacturer from

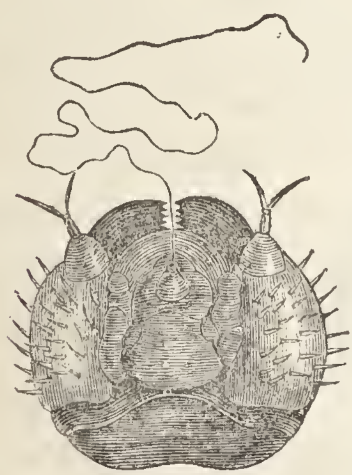


Fig. 13.

Fig. 14.

various parts of the world,—principally from France, Italy, China, and the East Indies. It is, however, produced in many other parts of the world; as Sweden,

Russia, and America. From the East Indies various kinds of silk are obtained from the wild moths I have before mentioned. The best-known of these is the tussah silk, produced from a moth in the western parts of Hindostan. The Chinese tussah silk is said to be obtained from the great atlas moth. North America produces three species of native silkmoth; the one, feeding on the willow and plum, in Louisiana; a second, living on the walnut and liquid amber, in Georgia; and a third, reared on the apple, oak, and beech, in Georgia. The silk is inferior; but it becomes an interesting question as to whether some of the worms of these moths could not be profitably reared in England.

Fig. 15.

The way in which the silk is obtained is, to feed the worms with mulberry-leaves in a suspended basket, as in this drawing. (Fig. 15.) In a few weeks the worm spins its cocoon; several of these cocoons are then taken and placed in vessels heated with water, or in an oven, in order to destroy the chrysalis. The silk is then reeled: each end of silk is placed upon a reel, and as the reel goes round, the silk is wound off, and then formed into what are called hanks. (Fig. 16.)

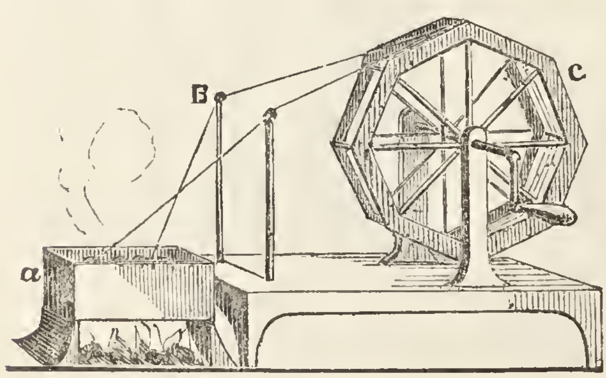


Fig. 16.

Now, the raw silk next is manufactured into what is called spun silk, and it is twisted on to wheel spindles, and then afterwards re-wound into the form of small hanks, or skeins. There are three kinds of spun silk—*singles, trams,* and *organzines,* or thrown silk. Singles consist of a single reeled thread, twisted to give it strength and firmness; tram is formed of two or more threads twisted together,—in these states it is used for forming the shoot or weft; organzine, or thrown silk, consists of two, three, or more singles being twisted together in a contrary direction to that in which the singles of which it is composed are twisted.

The next process to which the silk is submitted is dyeing. It is first scoured, to get rid of a glutinous substance called gum. If the silk, however, is not to be coloured, but is intended to be made up white, then it is not submitted to this process. We have black, blue, and red dyes, of various shades: for black, galls and iron, with indigo, are the most frequent substances used; but there is frequently a great fraud committed in dyeing silk black: the silk is made to weigh sometimes 25 per cent. more when dyed than before. This is done by adding sugar, as silk will absorb a considerable quantity of this substance, which makes it heavier and to assume a stouter appearance. You may easily ascertain the presence of sugar by the taste. The red colours are given by the agency of cochineal and of lac, which are produced by insects. Thus the cochineal and lac insects contributing their produce, with that of their brethren the silkworms, render "silken scarlet" truly an insect fabric.

It would be out of my province to deal with the

different manufactures, but I will call your attention to the great variety of them. There are plain silks and figured silks; then we have the beautiful surfaces called satins and satinettes; we have also a very peculiar form of silk which is made into shawls. We have silk lace, and large quantities of this lace are made by machinery; but the best silk lace is finished up by hand. There are hundreds of women employed in this interesting manufacture in the neighbourhood of Nottingham. Then there are damasks and brocaded silks. Poplin consists of four parts of wool and one of silk; and there are many other mixed fabrics in which silk forms a part. Nor must we forget crapes, and the infinite variety of ribbons, the product of the looms of Coventry, Derby, and other places. Now, during the manufacture of silk into these various fabrics, we have a large quantity of waste. We import into this country cocoons which have had their silk reeled off, and they are called knubs and husks, which still yield silk used for coarser goods. There are also other forms of silk waste, which are spun and woven into a variety of fabrics, so that no portion of the fibre is lost at all. Even in China, after they have used up the knubs and husks, they take the chrysalis and make the most of the delicious morsel by converting it into a stew, which is used as an article of diet.

The little glands which form the silk are remarkable for the strength of their substance, and an article is manufactured from them called silkworm gut, which makes an exceedingly strong and useful line for the hook of the angler; and those who are fond of the "gentle art" will appreciate this "silkworm gut."

Even ladies' bonnets have been made of this substance. So that you see there is hardly any part of the little creature which is not more or less useful to man.

I cannot now allude to other insect products. I have brought forward the silkworm insect as an instance of a contribution of the invertebrate tribe of animals to the materials used by man in his arts and manufactures. In the next Lecture I shall consider the subjects of wool and hair, and their importance in manufactures.

Fig. 1.

ON WOOL.

I PROPOSE in this Lecture to leave the invertebrate animals altogether, reserving shell-fish and other creatures belonging to that group for another, and now proceed to bring before you some of the products of the higher classes of animals—the vertebrate animals.

There are various ways in which we might treat this subject. We might take up the animals according to their natural-history classification, but the objection to that would be that we should have to repeat a great deal in one class of what had been said in another; so that I propose, first, to take the whole group of these animals, and speak of the various parts of the whole of those which are used in the arts and manufactures.

All animals, as well as plants, are covered with what is called an epidermis. If we take a brush and

brush our hands or arms, we shall observe a quantity of dust to fly off. If we collect this dust, and put it under the microscope, we shall find it composed of a series of scales or cells, such as are seen in this drawing (Fig. 2). Now these are called epidermal

Fig. 2.

cells, and the whole of the membrane which lies at the top of the skin is composed of these cells, of which Fig. 3 is a section. The mass of matter which you see lying above the true skin is called the epidermis. It is this part which rises when we apply a blister to the skin; the water coming from the true skin beneath, and pushing it up. This epidermis extends throughout the whole animal kingdom, and is not confined to animals but is also to be found in plants. If we look on the outside of plants, we shall find in all, except water-plants, that there is a delicate membrane lying on the surface, composed of cells which are much more dense, and firm, and closer together than

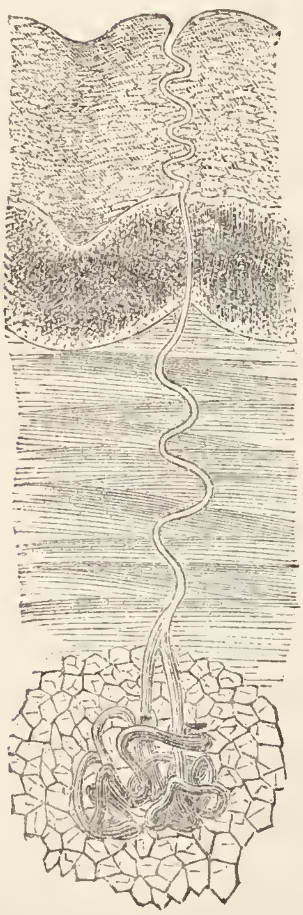


Fig. 3.
Sudoriferous Glands.

those which lie immediately under. This external membrane is called the epidermis in plants as well as in animals. In both plants and animals, appendages are found upon the epidermis. In plants they are called warts, villi, hairs, or prickles, according to their form and hardness. When the hairs have cells at their base, which secrete a poisonous matter which stings us when we touch them, we call them glands, such as the hairs of the common stinging-nettle. We find, also, that when this membrane is carried into the interior of the organs of the plant, it forms a softer set of hairs than it does when it is on the exterior; thus we find that it lines the interior of the date, the orange, and other fruits, but above all it lines the interior of the fruit of the cotton-plant. When the epidermis extends from the outside to the inside, it forms a membrane called the epithelium. In the same way as hairs grow on the epidermis, they will grow on the epithelium, and the most important article of our manufactures is this hair that grows inside the cotton fruit. These cotton hairs, as may be seen under the microscope, have a little twist given to them during their growth, a permanent bend, which enables us to twist them into a thread, and from these threads to form a fabric, the manufacture of which distinguishes us among the nations of the world. Whatever importance our manufactures possess, we owe to cotton first; and then come wool, and silk, and leather. In our manufacturing industry we use the hairs of animals, and they may be woven in the same way as the hairs of plants. I want to draw your attention to the fact that this epidermis of animals will produce hairs

just in the same way as it produces hairs in plants—not only hairs but a varicty of organs which we do not recognize by the name of hairs. We should hardly call a corn on our toe a hair, and yet it is an epidermal appendage of the same character as hairs. The horn of the rhinoceros is formed of the samc materials as a hair. In the invertcbrate animals,—crabs, lobsters, insects, and shell-fish,—if you examine them you will find that this external membrane has become converted into a skeleton, and thus we call them epidermal skeletons. And if we pass from those lower animals to the vertebrate animals, we find them producing a variety of appendages upon their skins, the object in view being the preservation of the life of the animal. Takc the fish, for instance; the most distinguishing features of the fish are its scales, which are formed in the same way as hairs—we divide fish according to the form of their scales. There are two forms of scales, which are vcry common among our fish of the present day; and there are forms which are common in extinct fish, and it is by these the palæontologist is able to group thc species of fish. The crocodiles, the alligators, and large numbers of the saurian reptiles, are protected by epidcrmal scales; we even find that some of thc mammalia, as the long-tailed manis and the armadillo, are clothed with scales. The feathers in birds are modifications of the same organs, and we shall find amongst the mammalia organs very much like feathers, in the quills of the porcupine and hcdgehog. Then we have in the mammalia hoofs and horns, which are epidermal appendages.

The claws and bills of birds, and our own nails, are

all formed of the same materials as hair. Now, I want to call your attention to the way in which this hair is formed. In the skin there are little depressions, little holes, follicles; some have hair and others have no hair. Those follicles are filled naturally with an oily matter; but when the hair is formed, we have little blood-vessels supplying the lower part of the follicles; and the supply of the cells depending upon the quantity of blood or materials for nutrition at the bottom, we find that the cells grow faster here, and thus the hair is, as it were, pushed out. Here is a drawing of the human hair in its follicle (Fig. 4). Corns are formed in the same way, but not in a follicle; when you have a tight boot, you produce an irritation, which nourishes the epidermal appendage of which so many complain. So it is with warts: they are an excessive secretion of these epidermic cells.

Fig. 4.—Follicle of Human Hair.

The subject I wish to bring before you now is wool, not hair; but wool is nothing more than a modification of hair. We call that wool which has a tendency to curl. We say when a man's hair curls and is crisp, that he is woolly-headed, and there are woolly-headed races of mankind. Well, that tendency, which we occasionally find in the human race, is constant in certain animals which yield the substance called wool, and we shall find that the growth of this wool is attended with alterations, by which it can be used for purposes

for which we cannot use hair. We cannot weave human hair—we cannot felt human hair—we cannot make such warm garments with hair as we can with wool. If you put a piece of human hair under the microscope, you will find that there are little markings running across it (Fig. 5); but if you take the hair and

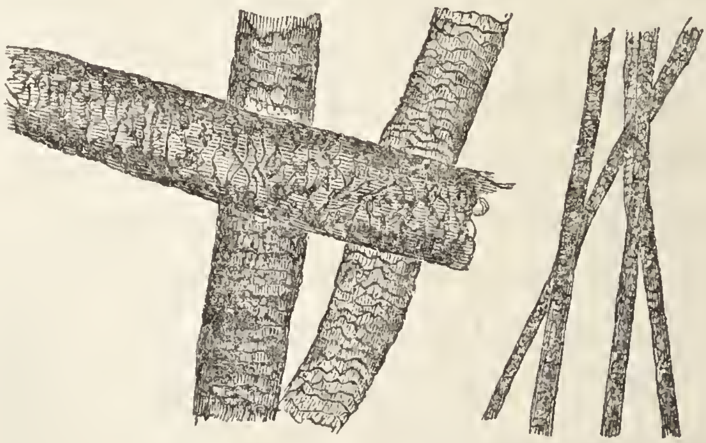


Fig. 5.—Human Hair.

boil it for a length of time, treating it with sulphuric acid, you will split it up into little cells having the character of epidermal cells. Now, if you put the wool under the microscope, you will find you have lines running across, but much more serrated than they are in the hair. Here are representations of Russian, African, and Chinese sheep's wool, and of camels' wool. Thus you see the microscope proves to us that the markings are much more prominent in wool than in what we call hair. This is dependent upon the fact that these woolly hairs possess looser scales in their structure, and this is the reason

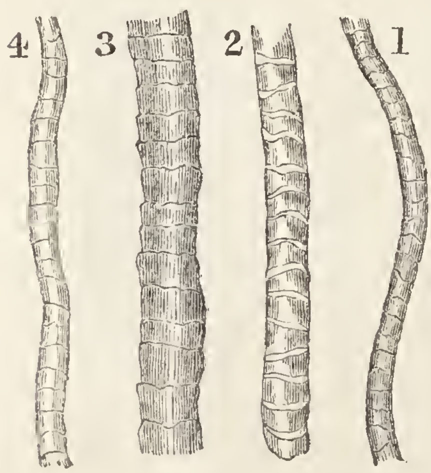


Fig. 6.
1. *Russian Wool.*
2. *Cape* ,,
3. *China* ,,
4. *Camels'* ,,

of their being so useful in the arts. The woollen manufacture depends upon the imbrications which you see in the kinds of wool.

Calculations have been made as to the number of these serratures. Mr. Goss finds that the finest Saxony wool contains 2,720 of these serratures in a single inch, which will give you some idea how much wool is magnified in our drawings. Saxony wool is used for making superfine cloth, and it is a kind of wool that we never get from English sheep. Wool with the finest serrations is used for the finest cloth. Merino wool presented to Mr. Goss 2,400 serrations (Fig. 7).

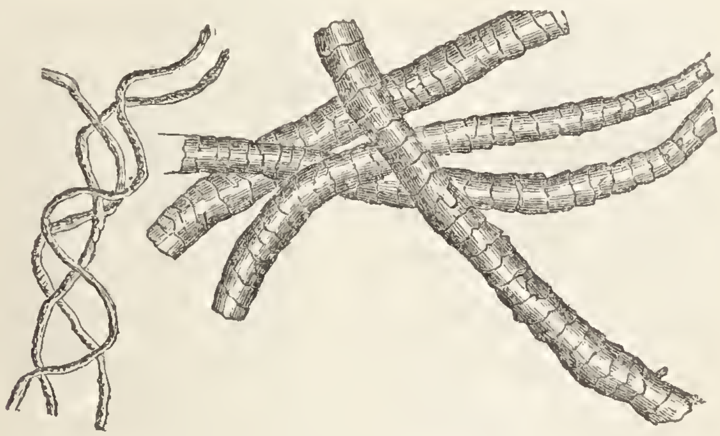


Fig. 7.—Spanish Merino.

Now we come to our own Southdown fleeces, which are known by manufacturers to be inferior to the Saxony wool; and Mr. Goss found in Southdown wool (Fig. 8) 2,080 serrations to the inch; and when we come down to

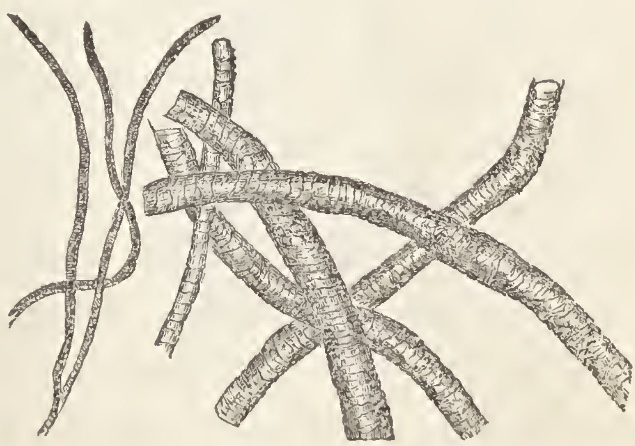


Fig. 8.—Southdown Fleece Wool.

our Leicester wool, which is still less valuable for cloth, we find only 1,850 of these serrations (Fig. 9).

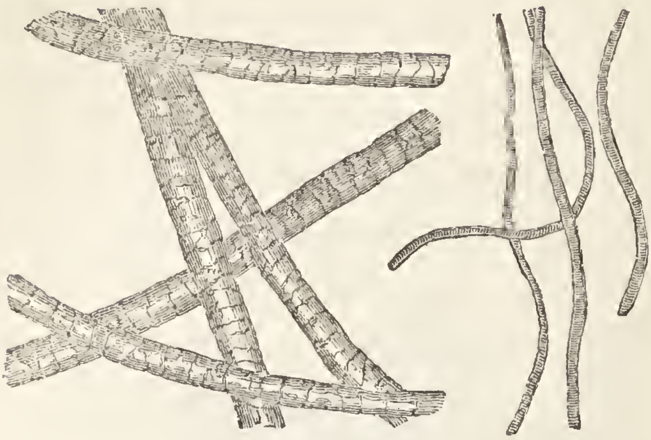


Fig. 9.—Leicestershire Fleece Wool.

These observations render it exceedingly probable that the manufacturer would be able to detect the quality of the wool by the use of the microscope. It is all very well for men to say, "We can use our hands and our eyes, as we have done from the time of Adam, and we do not want any of your new-fangled instruments;" but that is like a man rejecting the use of one of his eyes because his grandfather had lost an eye. By the use of the microscope, we can detect qualities in the wool hitherto unknown even to the practical man. These serratures, then, are of great importance in relation to the uses of wool; and it would appear that the process which is called felting depends entirely on these little serratures becoming entangled one in another. A piece of cloth may be felted without weaving. All cloths go through the tremendous knocking of the felting process, but many fabrics are made by the felting process alone.

You cannot too early know the distinction between the uses of wool; one set of things is converted into what we call cloth by the felting process, and another set is converted into what we call worsted or stuff, which are made from the hair which does not felt well, and it is the proportion of these serratures that deter-

mines the destination of the wool. The longer the wool, the less the number of serratures in the inch, and the shorter the wool, the greater the number of these serratures in the inch. Short wools are therefore preferred for the cloth-manufacture, and long wools for the worsted-manufacture. We have instances of the use of wool for felting, which show that the process of felting has been known almost from time immemorial. As to other hairs, nearly all *rodent* animals produce hairs that will felt; as the stoat, the mouse, the sable, the rabbit, and the hare (Figs. 10, 11, 12, 13). Here I may remind you that the beaver

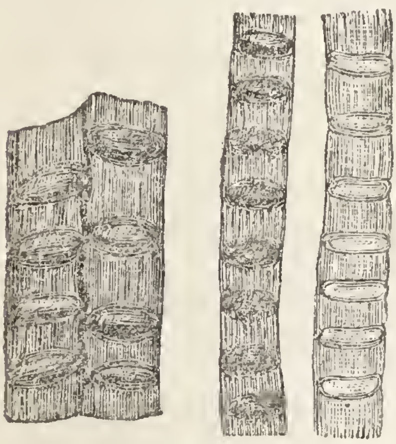


Fig. 10.—*Rabbit Fur.*

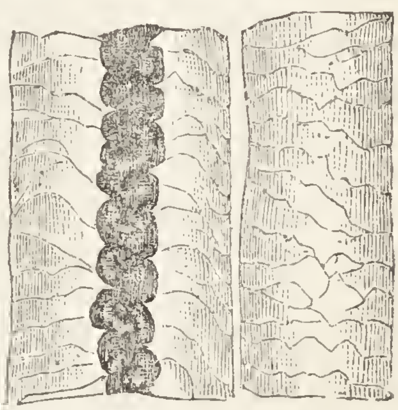


Fig. 11.—*Misquash.*

Fig. 12.—*Mouse.*

Fig. 13.—*Squirrel.*

hat, which is becoming almost as scarce in this country

as the beaver himself, is made by the process of felting (Fig. 14).

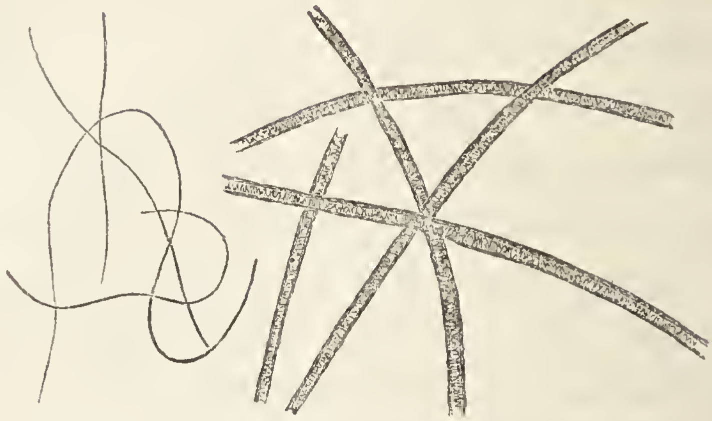


Fig. 14.—*Beaver Fur.*

In making beaver hats, the hair is mixed with cottonwool, which, although it will not felt itself, has the curious property of facilitating the felting of the beaver hat. The beaver hairs are beaten together with the cottonwool, which comes out to the surface like cream upon milk; it is then taken away, and the beaver felt is made into the hat. I have in my possession a beautiful specimen of cloth, which consists of the hairs of the rabbit, which have been woven and felted. This cloth, I should think, is likely to be useful for a variety of purposes. I have sometimes suspected, that it is not *altogether* due to these serrations—these imbrications so clearly developed in the wool of some animals, that felting is due; for in rodent hairs you always get a kind of hole or cavity in the interior, which allows the hair to yield to pressure, so that it is reduced to a third or half of its bulk by the process of felting.

I now come to the chemical nature of hair. I told you in the last Lecture that the animal kingdom was distinguishable from the vegetable kingdom by its

fabrics being generally composed of gelatin instead of cellulose; and yet that was a generalization not without great exceptions; for, in fact, hairs and silk, which I mentioned in my last Lecture, are not composed of gelatin. When we put them into boiling water, they do not dissolve, for we could not wash them in hot water if they did; but the composition is, after all, very nearly that of gelatin. There is some difficulty in ascertaining what is truly the nature of this epidermal substance, when it assumes the form of the hair, the nail, the hoof, the horn, the quill, and of the scale. These substances have been examined by the chemist, who has not, however, found anything definite in them. They contain carbon, oxygen, hydrogen, and nitrogen; but the real nature of the compound is not well understood. It seems probable, that when this matter has been used as muscle and nerve, a certain quantity passes to the skin, and there it forms the epidermal organs; but during that process it combines with a quantity of sulphur,—for all these substances contain sulphur, and that is how they are distinguished from gelatin, which does not contain this substance. This is all I can say with regard to the chemical composition; but I have no doubt the time will come when the chemist will understand of what these epidermal appendages are composed.

I come now to speak of the sources of wool. Everybody knows we get wool from the sheep. What is a sheep? Can anybody tell me the difference between a sheep and a goat? Yes, you say. Then, if you can tell in a very few words, you will confer a benefit on the naturalist. You find that the wild sheep pass

into the wild goats, and so closely resemble each other, that the naturalist is puzzled to know where one begins and the other ends. Of wild sheep, there is the *Argali,* which lives in certain portions of Asia, and is distinguishable from our sheep; and there is also the *Argali* of America—the sheep which is called *Ovis montana*; then there is a sheep which inhabits the islands of Greece. It is very certain that the old sheep which we read of in the Bible was not a descendant of the American *Argali* in any way. Then the question is, whether it is descended from the *Argali* of Asia, or the *Musimon* of Crete and Greece. There is considerable difficulty in getting at the origin of our domestic animals, and so we speak of our domestic sheep as an independent species, the *Ovis Aries.* Now, the great distinguishing features of our sheep have been maintained through a long period of time; the sheep we have at present seem to be identical with the sheep of old. The sheep of Judæa seem not to have differed from the sheep of the present day. When we read in the Bible of the tending of sheep, and their management, we feel that the sheep of that day were like the sheep of the present day—their habits were the same, their domestication was the same, and their uses were the same; for we find the man of that time eating the mutton and using the skins for clothing, until he learned to weave the wool into cloth garments.

We have what are called breeds of sheep, and those breeds of sheep are somewhat difficult for persons not acquainted with agriculture to determine. We may divide them into the old mountain sheep, the early inhabitants of our island, and those sheep more

recently reared, which are sheep of the plains. We all know the little Welsh sheep, having a leg not weighing more than two or three pounds, scarcely enough for a strong man's dinner, and they have so small a crop of wool that it is hardly worth while shearing them, and they are going out of fashion. There are, however, people from Wales who like Welsh sheep, as the Scotch like Scotch sheep; and thus the breed is kept up. But there would have been no Leeds and no Bradford, if there had been none other than Welsh sheep. Then, we have the Southdown. There is the black-faced Scotch sheep, which is also an excellent bearer of wool, and the Cheviot. Little sheep generally bear small fleeces, the Welsh and Irish generally not more than 2 lbs.; and the Leicester as much as 8 lbs., and in America a sheep has been reared that produced a fleece of 18 lbs.; so that you see that the tendency in this country has been to get a large amount of wool. At the same time, we do not produce in England the finest kind of wool. The long-woolled sheep yield a valuable produce; but it is the short-woolled sheep which produce the most valuable. The sheep of Germany, of America, and more especially of Australia, all produce better wool than English sheep. These forms are represented by the Spanish sheep. The Merino sheep, originally reared in Spain, produces the finest quality of wool for the manufacturer (Fig. 15). This wool is short, covered with a sticky secretion; but we can easily see that this wool makes the finest quality of

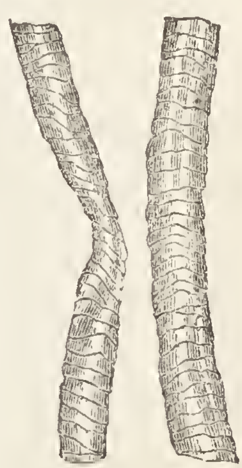


Fig. 15.—*Finest Spanish Wool.*

cloth that is worn. Hence it was, that many years ago attempts were made to introduce the breed of Merino sheep into England. It succeeded to a certain extent, but our climate was too damp and too cold to develop the wool of these sheep, and I believe there is not a single flock of Merino sheep in this country now, although thousands of pounds have been spent in the attempt to domesticate them. Our manufacturers can now obtain their Merino wool from Spain, but at one time the law forbade the importation and exportation of wool, and we were then confined to the produce of our own soil. It was at that time that the sheep were introduced. Spain has lost much of her prestige and much of her commerce lately, and when one hears of the climate of Spain and the vast resources of that country, one grieves to think that she is doing so little among the nations of Europe. But what has not been done by Spaniards has been done by Englishmen. A few of these Merino sheep found their way to Botany Bay. I do not mean to say that any cunning sheep-stealer carried away a flock of those sheep while he was paying the penalty of his malversations; but at any rate they were sent there, and were afterwards neglected; but in spite of that they flourished and increased, and from that small beginning has commenced an enormous development of sheep-farming in Australia; and now our largest supply of best wools is from Australia. So that you see, after all, Providence has directed the sheep in the way of the Englishman, who has turned it to his advantage.

We get other kinds of wool. I may mention the Saxony wool, which is perhaps the best spinning wool

in the world, and furnishes the fine Saxony cloths. We obtain, also, a considerable quantity of fine wool from America, and America is carrying on a woollen-manufacture from the production of its own sheep.

It would seem almost hopeless for the English farmer, while he seeks to produce fine mutton, to compete with America, Germany, and Australia, in the production of wool; but, at the same time, the mixture of breeds has presented us with wool of a greatly-improved kind, and the day may come when, at the same time that we have the best mutton on our tables, we may produce the finest wool for our cloths.

Wools are brought into this country from China, the East Indies (Fig. 16), and other parts of the world.

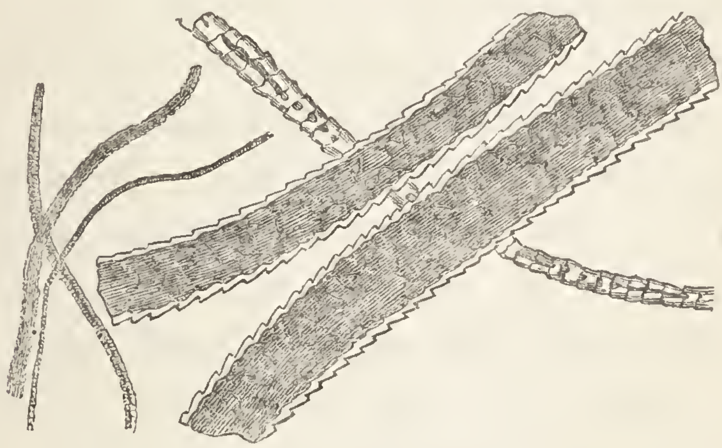


Fig. 16.—East-India Wool.

Other animals yield wool as well as the sheep. The camel yields a wool which is occasionally woven. It is woven by the women of Persia into a kind of coarse garment very generally worn in certain districts. Other creatures which come more actually into competition with the sheep, are the goat, the llama, the alpaca, the vicugna, and the guanaco. The common goat does not possess anything like the quantity of wool that the sheep does, but in certain parts of the world the goat produces

very fine wool (Fig. 17), which has been manufactured into the most costly garments. It yields a fleece of from $1\frac{1}{2}$ to 4 lbs. of fine fleecy long hair. In 1848, it was first brought into the markets of Europe under the

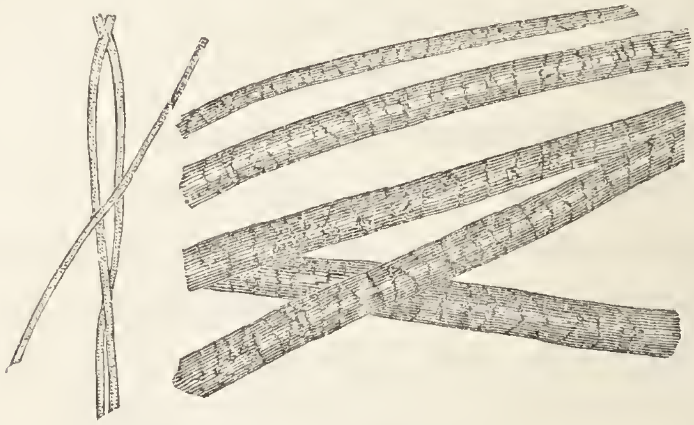


Fig. 17.—*Mohair.*

name of mohair. What we call velveteens and plushes are mixtures of cotton and wool; and sometimes silk and wool are mixed, and the wool of the Angora goat is particularly well adapted for these mixtures. There is a goat in Cashmere which yields an exceedingly fine wool. We know very little of the nature of this wool, but this goat yields the wool that is employed in the manufacture of the costly and beautiful Cashmere shawls. This goat yields a flecce, of which about 30 ounces are capable of being manufactured into a shawl a yard and a half square, and the worth of the 30 ounces is 8*s*. or 9*s*. Then why do these shawls cost sometimes hundreds of pounds? In answer to that question, I will read a passage from the Catalogue of this Museum:—

"Thirty ounces, valued at eight or nine shillings, is all that is required in the manufacture of a shawl a yard and a half square. The immense cost of these shawls in the European market is, therefore, a subject of much wonder to those unacquainted with the history of their manufacture and transportation. A heavy duty is first paid upon the wool; then a further tax upon the yarn when it reaches the bazaar; and the manufactured shawl. when taken to

the custom-house, is further taxed according to the discretion or caprice of the collector. If intended for the European market, the shawls have yet to pass through the ordeal of still heavier exactions. They must be borne from Cashmere across the Indus to Peshawur, on the frontier of Afghanistan, a journey of twenty days, upon the back of a man; the road being often impassable by camels or mules; deep precipices being crossed upon suspension-bridges of rope, and perpendicular rocks climbed by means of wooden ladders. At various stages of this journey taxes are exacted, amounting to 36*s*. or 42*s*. in the aggregate. From Peshawur, to near the confines of Europe, tribute is paid at many custom-houses, and the forbearance of the marauders of Afghanistan and Persia, and of the Turkomanic hordes, must also be purchased at a high price. The precious burden is thus conveyed to Europe over the Caucasus, and through Russia, or, as is now frequent, through the Turkish provinces to Constantinople."

You see, our friends in Cashmere are not aware of how fully we have discussed the question of free-trade, and determined that it is for the better extension of trade. You need not wonder, then, that those beautiful shawls, manufactured from this hair of the Cashmere goat, should sometimes reach such a wonderful price before they pass the rocky portals of the Valley of Cashmere.*

But I now pass to a family of animals that has recently yielded a large increase to our cloth-manufacture. I allude to the alpaca tribe or family, allied to the camels and dromedaries. When Pizarro conquered Peru, he found these animals employed as beasts of burden, and their wool used for making clothing. The Peruvian government has placed an embargo upon the exportation of these creatures, so that we have only now and then seen them as

* The influence of the Scinde Railway in opening up the trade of Cashmere has been very remarkable. The following statement is taken from the report of the directors of the Scinde Railway Company: In 1856-7 there were exported Cashmere shawls to the value of 25,000 rupees; in 1857-8, 534,000 rupees; and in 1858-9, 964,000.

curiosities in the collection of our Zoological Gardens; but in 1846, it appears, some of this wool found its way to Bradford.

For the successful manufacture of this wool we are indebted to the energy and enterprise of Mr. Titus Salt, who, in the application of this material to the making of cloth, has succeeded in laying the foundation of one of the largest manufacturing establishments in this country, and has conferred a blessing upon his own country, as well as the countries in which the animal is reared.

The length of the hair (Fig. 18) of the alpaca renders it of considerable value for mixing with goat's

Fig. 18.—*Alpaca.*

wool, silk, and other materials. There are four forms of these animals, very distinct from each other,—the Llama, the Alpaca, the Vicugna, and the Guanaco. The vicugna yields very fine hair, which is very much valued; but the alpaca yields the most useful hair.

I have mentioned the advantage of acclimatizing other animals. There would be no difficulty apparently in acclimatizing these animals in Australia, though, where they have been tried in this country, the rot has seized them, because of the tenderness of their feet. A few

months ago, several alpacas were secured, in spite of the jealousy of the Peruvian government, somehow or another, and sent over to Australia, where they have arrived; and I understand that a first crop of wool has been secured, and that the flock is flourishing. Such experiments as these should be more extensively and systematically carried on both in our own country and in our colonies.

I will now direct your attention to the manufacture of wool. The wool has first to be got from the back of the animal. Like all these other epidermal appendages, it is liable to be cast off. There is one peculiarity of this process, that if creatures do not throw off their epidermis by what we call a moult, it is constantly dropping away. We are continually moulting; but occasionally large quantities of hair come off at a time, and this also is moulting; at the same time, this process is a perfectly natural one. You see the process in the antlers of some creatures, and the horns of others—in the hair of all the mammalia, and the feathers of birds, and in the scales of fishes. Thus wool would fall off, but man comes in and prevents the falling and the trouble of picking it up, by shearing. Before shearing, the wool is washed. If you look at the fleeces in the Museum, South Kensington, you will see it is always stated that they were washed on such a date. This washing is necessary to make them available for the manufacture. At the base of the hairs, a compound is formed of oil and potash, which is a kind of natural soap, for carrying away the impurities of the hair, and the grazier takes advantage of this soap. Sometimes he uses various lyes, and the addition of substances for

killing insects, in this process of washing; but generally these additions are bad, and the only thing necessary is to take the animal and wash it in soap and water, and afterwards in clear water. The shearing takes place in the summer of the year. Everybody has seen the lambs staring at their mothers, on account of their altered appearance after shearing, and not being able to recognize them till their well-known bleat reassures them.

The next process is that of assorting or stapling. The wool obtained is not all long or short. Even short-woolled sheep have some long wool, and long-woolled sheep have some short wool. When the fleece is cut off the back of the animal, it is divided into wool of various qualities. Take as an example, a Southdown fleece; and I present you with the results of stapling such a fleece. You have—

1. Super wool, 1 oz. This is made into flannels, blankets, lists, tweeds, and coarse cloths.

Then we have,

2. Livery wool, 1 oz. Used for low cloths, as prison, army, navy, and workhouse cloths.
3. Grey wool, 2½ oz. Used for army, navy, prison, and workhouse cloths.

So that there is not much difference between 2 and 3, except that 2, perhaps, makes officers' clothes.

Then there is,

4. Prime white wool, 5½ oz. Which is made into cloth of all sorts; blankets, best flannels, tweeds, shawls, coburgs, and lists.
5. Choice wool, 2 oz. Used for flannels, cloths, blankets, tweeds, shawls.

Then there is,

6. Picked tegg, 1 lb. 7 oz. Used for tweeds, shawls, and blankets.

I do not know what picked tegg is. Then there is,

7. Super tegg, 6¼ oz. Employed for fringes, hosiery, yarns, and coach lace.

Then there is, finally, a long wool, of which there is about 3 lb. 8 oz. for yarns, fringes, shawls blankets, &c.

This process of stapling is a very interesting one. The persons who do it are called wool-staplers. They place the fleece on a table, and with their hands they sort out the different qualities; and it depends upon the object of the seller as to how it shall be stapled.

The wool having been stapled, it is next taken to the manufacturer. It is there scoured or washed. It contains a good deal of dirt of various kinds; it also contains grease, lye, and other animal matter, and it is exposed to substances giving off ammonia, which combines with the oily matter; and, after being thus scoured, it is submitted to pressure, in order to dry it.

When wool is to be made into black cloth, it is dyed at this stage of the process. When the manufacturer wishes to dye the cloth with lighter and brighter colours, it is dyed in the cloth. After it has been dyed, it is submitted to a process called "willying," which consists in arranging the wool in such a way that the fibres are laid parallel to some extent, and after this is done, a further process is employed of purifying, called "picking." Then comes the process of "scribbling," which is antecedent to "carding;" and this process seems to be almost as important as the felting, for it is

this carding which breaks up the wool into small pieces. In this state it has a greater tendency to curl: if you look at a piece of felted cloth under the microscope, you will see that the pieces of wool are curled (Fig. 19); and you cannot get the curl out of them. It is on this account that the carding which breaks it up is so important. After carding, the thread is made more dense by the process of "slubbing." Then the "spinning" takes place, and after that the "weaving." After weaving, the cloth is submitted to another process of "scouring," for they have added oil to it during the process of spinning, and they also cause the thread to pass through size, so that the threads may lie close together: so they add potash to get rid of the oil, and soap and water to get rid of the size. Then comes the most distinguishing process of the whole, and that is the "fulling." The fulling is effected by enormous wooden hammers, which are allowed to drop on to the cloth, and give it such a hammering, as no one would like to submit to, unless he were a champion of the prize-ring. By thus hammering the cloth, it contracts to a considerable extent, and is brought to a condition in which its strength is fully developed; whilst unfulled, it is weak, and easily torn, but now its filaments are bound more closely together and are not easily torn. After it has been fulled, it is again scoured, and then it is submitted to a process called "teazling,"—a process of brushing or raising. It consists in applying the ripened head or fruit

Fig. 19.—Fibre from a cloth coat.

of the common teazle (*Dipsacus fullonum*) to the cloth. The teazles are attached to a cylinder, which revolves upon the cloth, and the loose particles are raised, so that they may be easily sheared or cut off, to give the cloth the fine appearance it assumes. Man has invented no instrument which will take the place of the teazle (Fig. 20). It is remarkable for pro-

Fig. 20.—Fuller's Teazle during growth.

ducing at the end of the little leaves at the base of its flowers, called bracts, a spine which curves downwards, and thus acts as a kind of hook brush for pulling up the loose particles of cloth. Various substitutes have been tried,—pieces of wire have been fixed into a leather back, but without the desired effect. The

teazle is imported in large quantities from France and other parts of Europe. It is, however, extensively grown in England; but the English teazle is inferior to the foreign one. After the shearing and cropping have been gone through, then come the pressing, rolling, doubling up, packing, and sending to all parts of the world for use.

Before concluding, I must add a few words about worsted. Worsted differs from wool in the fact, that you use the hair not for the purpose of felting or carding, for they neither card nor felt in the worsted manufacture, but for the purpose of weaving. In fact, wool in the worsted manufacture is treated very much as cotton. The first process consists in abolishing those serratures of the wool which are of so much use in making cloth. The longest wools are selected, and these are smoothed down by means of oil and an iron comb, which is heated: this is called combing (Figs. 21 and 22). The prepared wool is then submitted to the pro-

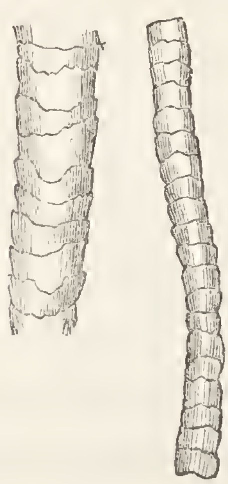


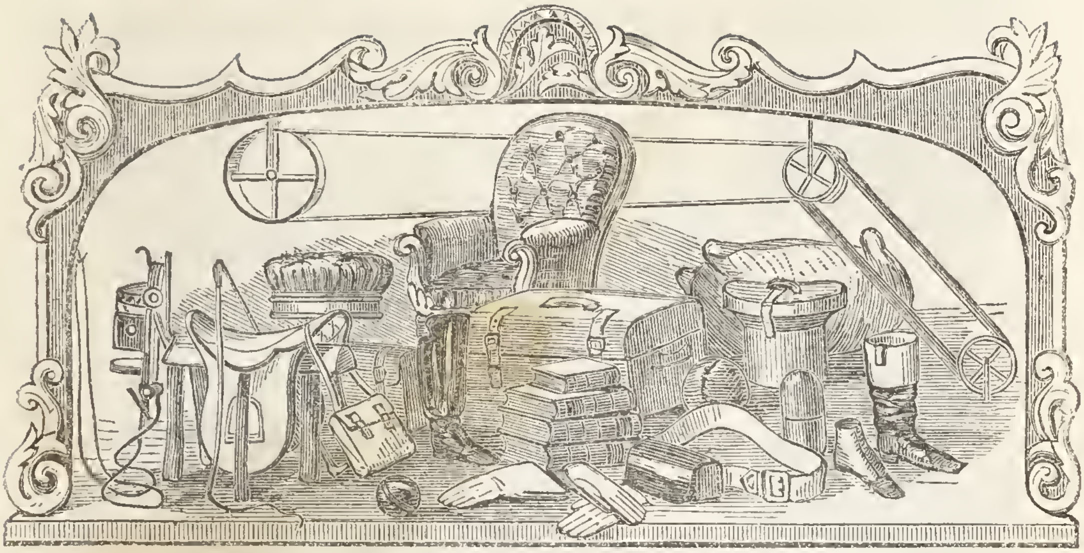
Fig. 21.
Wool ready for combing.

Fig. 22.
Wool for Worsted.

cesses of spinning and weaving, according to the purpose for which it is to be employed.

The woollen manufacture, then, consists of broad cloths, narrow cloths, carpets, blankets, flannels, serges, and tartans; whilst the worsted manufacture produces stuffs, bombazines, camlets, and shawls; and various mixed goods, as damasks, plushes, and velvets. The woollen produces a warm and heavy garment, while the worsted produces a light and loose, as well as warm garment.

Thus, you see the value of the culture of the animals around us. In course of time we may find, if we learn our lesson rightly, that there is nothing created in vain, and that whatever God has made, He has intended for the use and benefit of man.



ON LEATHER.

In pursuance of the course which I have commenced, I shall now speak of the skin of animals. In my last Lecture I drew your attention to that product of the skin which we call wool, and its various applications in the arts. I alluded to the fact that wool was one of the epidermal appendages, as they are called, of animals. I now pass over the use of other forms of hair, as horsehair, human hair, feathers, quills, hoofs, and horns, all of which are epidermal appendages. I shall come to them again, I hope, by-and-by, and be able to treat of them in a separate Lecture; but now we will talk of the skin, the substance out of which the epidermal appendages grow. I drew your attention to the epidermis in the last Lecture, and stated that the skin was composed of two parts,—the epidermis and the dermis

(Figs. 1 and 2). The epidermis is a membrane composed of several layers of cells on the external surface of the dermis, or true skin. If we scrape the skin, we separate a substance, which if we examine under the microscope, we find to be composed of a number of flat cells (Fig. 3); and if we examine deeper, we shall find that some of the cells are spherical; so that this outer portion is entirely composed of cells. This, then, is the epidermis or scarf-skin. The epidermis is continued in the animal — into the mouth, into the organs of respiration, and the interior organs, where it is called mucous membrane; and we find this mucous membrane is covered with scales, which are called epithelium. I only want to show you here that the skin is continuous with the mucous membrane; and you may

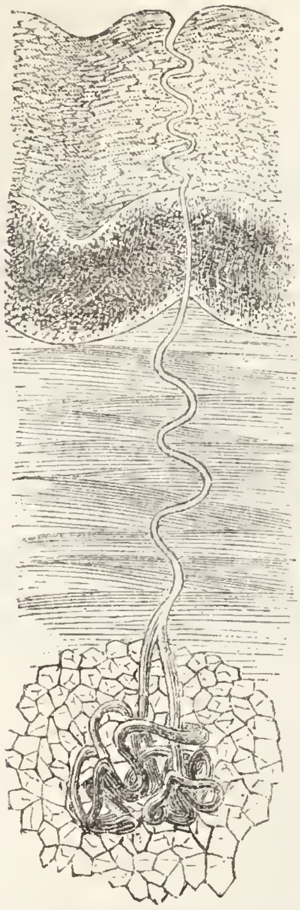


Fig. 1.--Epidermis and Dermis, showing the SudoriferousGland.

a. Epidermis.
b. Dermis.

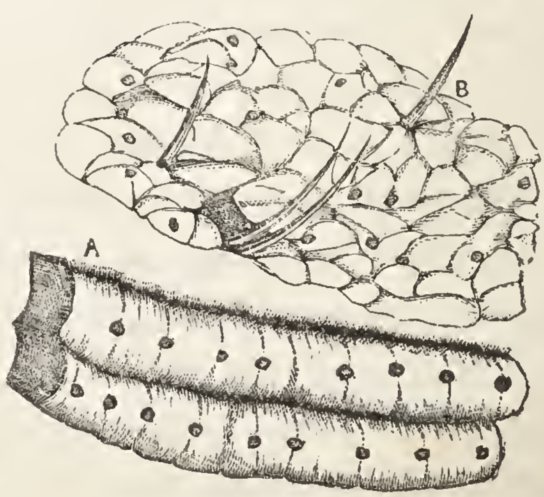


Fig. 2.—Epidermis—Surface View.
A. *Palm of Hand.* B. *Back of Hand.*

regard an animal as a sort of bag. When the internal organs are formed, the skin is as it were tucked in. But we have nothing to do now with the internal organs or membranes, which are, however, used in the arts. I have to call your attention to the skin itself.

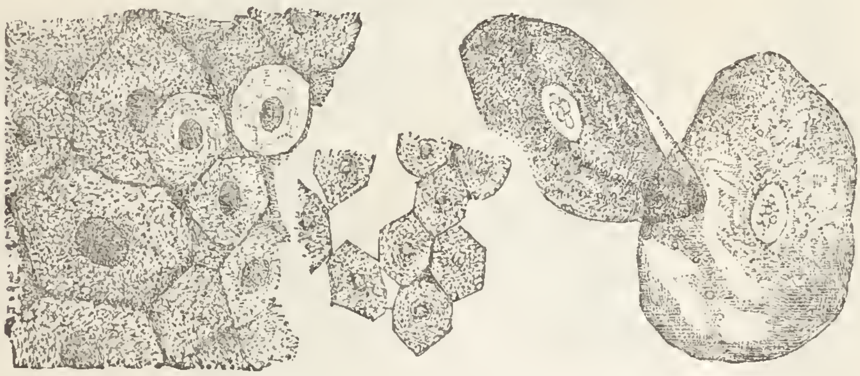


Fig. 3.—*Cells of Epidermis.*

There is one point, with regard to the epidermis, which I want to allude to before I leave it. The epidermis gives the colour to the animal; and not only does the epidermis give the colour to the lower animals, but it also gives colour to man. You know that there are some races whom we are fond of calling the "less-favoured races of mankind," which are black. Sprinkled among the epidermal cells you will find a quantity of polygonal cells, which are called pigment-cells, which give a dark colour to the skin. When these pigment-cells are absent, we call such persons albinos, and when those cells are abundant, we call such persons "blacks;" and in proportion to the number of these cells is the colour of the individual or the races of mankind. The origin of these cells is a very interesting question, and one not easily decided; but there is reason to believe that the original colour of mankind was black, and we have certainly no more reason to con-

clude that Adam was white than that he was black. There is no evidence of the one being the true theory any more than the other. These cells are found in that portion of the epidermis which forms the hair, and their presence or absence constitutes dark or light hair (Fig. 4).

Fig. 4.—Follicle of Hair.

It is the same in the lower animals: the black animals have these pigment-cells in their hair, whilst the white animals are without them. Again, these cells are so constructed as to reflect a variety of colours; and thus we have the various colours of animals, produced by the abundance or absence of these pigment-cells.

Passing from the epidermis, I come to the layer which lies below it. It is of importance to those who work on the skin to understand its structure. It is to a knowledge of the nature of the skin that much of the recent improvement in the process of tanning is due. The under layer of skin is called the dermis. It is that layer which lies under the part which rises when you put a blister on the skin. Now this is composed of a basement membrane, in which there are blood-vessels. The cells which compose the epidermis are produced by the agency of the blood-vessels, which consist of arteries which run in one direction, and veins running out in the other; so that this thick part of the skin is copiously supplied with blood-vessels. That these blood-vessels are present, we can see in the leather after it is tanned, as

in this drawing (Fig. 5). This fibrous condition arises from these vessels.

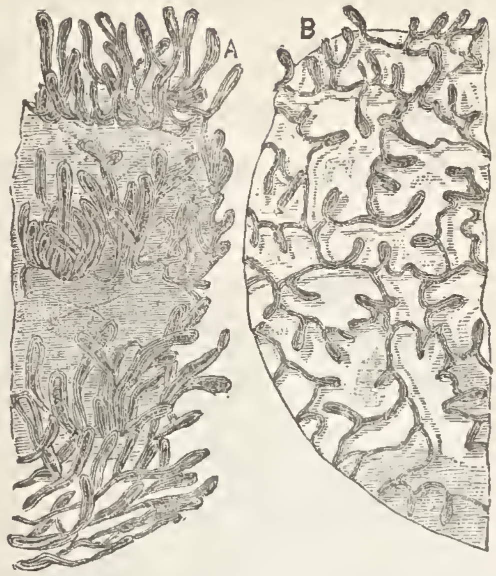


Fig. 5.—Blood-vessels of Dermis.
A. *Palm of Hand.* B. *Back of Hand.*

Then we have in the skin, which is the organ of touch, nerves running from the spinal cord. These nerves run up into little organs, called papillæ (Fig. 6).

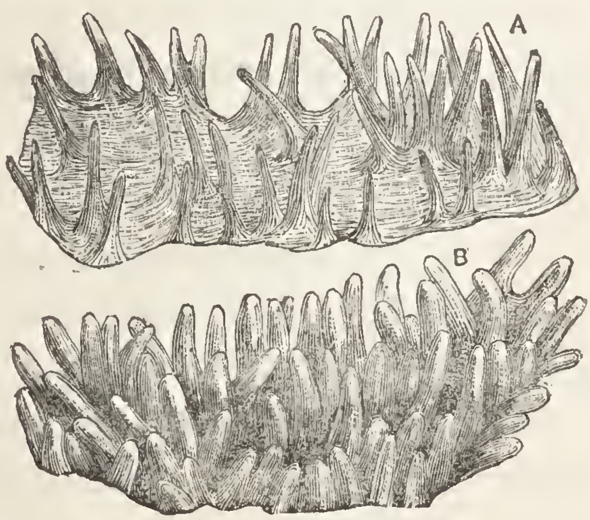


Fig. 6.—Papillæ of Skin.
A. *Palm of Hand.* B. *Back of Hand.*

They receive the nerves, which pass up through the dermis into the epidermis. These organs give the power of receiving impressions from outward objects by touch.

In addition to these organs, we have in the skin a number of glands. There is first a set called sebaceous glands or follicles. These little glands are intended to secrete a quantity of unctuous matter, which is constantly accumulating upon the skin, and which keeps the skin soft and pliable; and it is these little glands which frequently get blocked up, and form little black pimples on the face. They are frequently found accompanying the hair-follicle, as in Fig. 7. Sometimes these little follicles are the seat of an insect, called *Demodex folliculorum* (Fig. 8), and these are often found in the side of the nose. They may be squeezed out, and if placed under the microscope, are seen to be highly organized. They are not indications of disease, but their presence shows that these creatures have found the proper locality in which to exist, and they form a very interesting study to the naturalist.

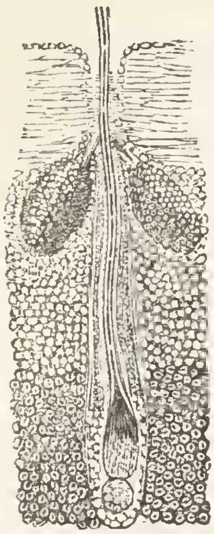


Fig. 7.
Sebaceous Gland, on each side a hair-follicle.

Fig. 8.--Demodex folliculorum.

It is the perspiratory glands to which I would call your attention more particularly. Here you have a drawing of these glands (Fig. 9); and you see they consist of a little tube, which runs into a gland, which is well supplied with blood-vessels, and is seated in the thicker part of the skin. The great function of these glands is to draw water from the blood, and they open by little pores on the surface of the skin; and if you look at any portion of the skin, the top of the thumb

for instance, with a common magnifying-glass, you will see that there are a series of elevated ridges and little pores, which are the terminations of these perspiratory ducts. Curious calculations have been made as to the number of these ducts (Fig. 2, B). Mr. Wilson states that there are 3,528 of these pores in a single inch of the skin;

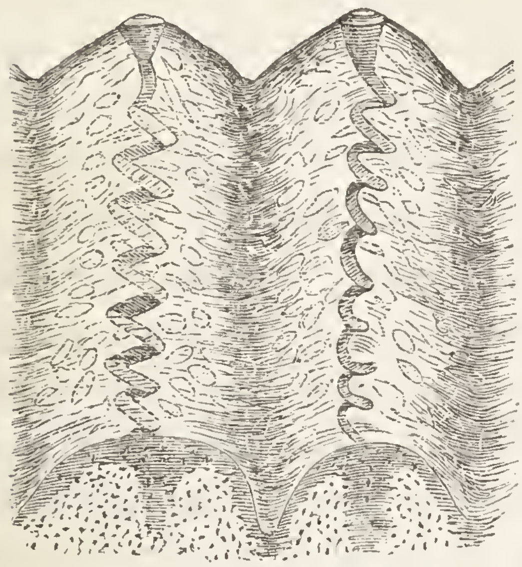


Fig. 9.—Epidermis, greatly magnified, showing the Perspiratory Glands.

so that in an ordinary-sized body there are not less than 2,300,000 of these pores; and the tubes have a certain length; and it is calculated that there are in the human body not less than 28 miles of this tubing. Now, the great function of these glands is to keep the heat of the body at a fixed temperature,—98 degrees. If it were not for that, our bodies would get up to a higher temperature than 98 degrees.

Thus you see that the skin is a very complicated organ. The chemical substance of which it is composed is principally the compound called gelatine, of which I have spoken before; and this gelatine can easily be procured from all parts of animals. We obtain it from the refuse of various manufacturing processes;

thus, it is procured from the clippings of hides, the refuse of bones, and other animal remains. I only mention this now to show you that the skin is principally composed of this substance called gelatine. This substance appears to be formed from the food, or, rather, from that portion of the tissues of our body which are sometimes called proteinaceous. If we take any portion of the living tissues of an animal, such as the nerve or muscle, we have fibrine in the muscle, and albumen in the nerve: albumen and fibrine are forms of protein. Mülder says, protein is composed of the elements nitrogen, hydrogen, oxygen, and carbon,—the four organic elements; and without entering further into the chemistry of this matter, I will just say, that the impression is, that gelatine is formed out of this fibrine and albumen after they have served the purposes of life in the muscles and nerves; it is then used for less-important purposes, such as making the walls of the cells, the skin, and other parts of the body; in this state it is about to pass away altogether from the body. In the next change, we find its elements in some of those acids and substances in the blood which are about to be thrown out. The fact of gelatine being present in the skin, constitutes the foundation of the art of making leather. There could be no tanning if it was not for the presence of gelatine. Gelatine is remarkable for being insoluble in cold water, but soluble in hot water; so that we may take any of these skins, and put them into cold water for any time, and they will not dissolve; but we can take the clippings of skins and dissolve them by heat; so that when we evaporate the water, we have the

gelatine left behind. Gelatine is used for making size, for making glue, and for a variety of purposes; it is also used as an article of diet. Even coarse bits of leather can be taken and boiled down, and made into gelatine, and then into jellies. Gelatine exists in the sound of the sturgeon and some other kinds of fish, and is procured under the name of isinglass, which we use for jellies. One remarkable feature of gelatine is, that when it comes in contact with a substance which is known by the name of tannic acid, it forms an insoluble precipitate. And here is a very remarkable thing worth a moment's thought, that two soluble substances meeting together should form an insoluble substance. If we take some tannic acid and add it to a solution of gelatine, we get a precipitate; this precipitate is called *tanno-gelatine,* and is of the same nature as the substance formed by immersing a piece of skin in tannic acid. It is due, then, to the presence of gelatine in the skin, that the manufacture of leather, by means of tannic acid, is carried on. But before speaking of tannic acid, I would just say this, that although, when we boil skins and other parts, and get gelatine, which we separate, yet there is no proof that this is the identical substance which is contained in the skin or in the animal substance before it is boiled; it is perhaps wrong, therefore, to say that leather is merely tannic acid and gelatine, because we do not boil the skin and convert it into gelatine before it is made into leather. Then, what are these tissues composed of? Why, they are composed of a *gelatigenous substance,* which, if you put it into hot water, forms gelatine. Then, what is

it? You must put the question to a more profound physiologist and chemist than I am. The question is, I believe, still an open one to determine what this substance is. We do not yet know everything about leather, and what I want to show you is, that however much the chemist may know, there is still a great deal more to learn; and that whatever encouragement chemists have met with, there is still a great deal left to clear up and to study, by which the intelligent workman may advance his own interest, and add to the welfare of the community. It is not, then, to be taken as a settled question that gelatine is the substance which we convert into leather, in the same way that the tannic acid and the gelatine, mixed together, produce an insoluble substance.

Our next question must be, what is tannic acid? Tannic acid is a substance that has been discovered to be present in the barks of all those trees and in all vegetable matters which have been employed by the tanner in converting skins into leather. This substance, when first discovered, was called *tannin.* It is, however, now found that it is not a neutral substance, but that it is capable of combining with the oxides of the metals as an acid, and it is called tannic acid. The chemical equivalents of this compound are carbon 28, hydrogen 9, oxygen 17. Those who recollect the chemistry of plants, will see how easily vegetable tissue of any kind may be changed into tannic acid. Wood is composed of carbon 12, hydrogen 8, oxygen 8; and you see how little change is necessary to convert cellulose into tannic acid. Double the carbon, leave the hydrogen very near as it

is, and add a little more oxygen, and the change is complete. Then, if you take the food of plants, which is chiefly water and carbonic acid gas, in them you have carbon, oxygen, and hydrogen. If you take 28 parts of carbon, and the quantities of oxygen and hydrogen which you find in carbonic acid and water, and take away the excess of oxygen and hydrogen as necessary to other functions of the plant, you get tannic acid. Now, there is another acid which is constantly formed with it, and this is gallic acid. Gallic acid is called so from the nut-galls, in which it is found in largest quantities. There is a great variety of these galls: they are always found on plants containing tannic acid. If you add three proportions of hydrogen and three proportions of oxgen—that is, three proportions of water—to the tannic acid, you get the real proportions of gallic acid. Thus we find that tannic acid is easily convertible into gallic acid, at least on paper.

Why I mention this gallic acid is, that it will not tan — it will not form an insoluble precipitate with gelatine—it will not combine with the hide at all. So you see, if tannic acid can be converted into gallic acid by the action of water, it is a matter for thought and inquiry to the tanner—to prevent the loss of tannic acid and to avoid the production of gallic acid. There are certain conditions in which tannic acid will rapidly run into gallic acid—by free exposure of tannic acid to the air, it forms gallic acid, and by taking the old tanning material, and adding to it tannic acid, you find that this used-up substance will actually start the series of changes by which tannic acid is converted into gallic acid. There are in fact several processes and several

circumstances under which tannic acid, which is so useful to the leather-maker, becomes converted into gallic acid, which is of no use at all. The only use of gallic acid that has been suggested in the process of tanning, is that it may soften the skin. Sometimes the skin is put into sulphuric acid to soften it. Now, the gallic acid may act as the sulphuric acid does, by opening, as it were, the pores of the skin, and allowing the tannic acid to come in. It is, however, a fact that leather which is produced by means of tanning substances which do not form gallic acid, is not liked by the shoemaker, or by those who buy leather directly from the tanner. Those who are familiar with leather know that there is on the outside of it what is called "bloom," which is a peculiarity of the surface of the leather; it is like the bloom upon the peach or the plum. This bloom on the leather can be rubbed off with the fingers, and the leather-buyer always prefers leather with the bloom on. It would appear that unless a certain quantity of tannic acid is converted into gallic acid, you get no bloom; and therefore the tanner is obliged to use a certain portion of gallic acid, in order to supply his customers with this bloom, as a matter of taste.

Before speaking of the sources of tannic and gallic acid, I would call your attention to the fact of their forming black compounds with the salts of iron. Leather itself may be made to turn black upon the application of iron. If we add a solution of iron to tannic or gallic acid, it turns black. These compounds are used for dyeing cloth and other materials black, and nut-galls are used for the purpose of producing our common black writing-ink.

The plants which yield tannic acid are very numerous; and just as chemistry has made inquiry into the nature of materials employed in the arts, have we found the substances which contribute tannic acid become more numerous. The tanner of old used oak-bark. The bark of the old English oak (*Quercus Robur*) was the source of the tannic acid, which has been employed from time immemorial, and to the present day it is the oak-tree which yields us the largest quantity of bark. The consumption of oak-bark in this country is between 200,000 and 300,000 tons in a year; while there is not more than 5,000 tons imported from other countries. The bark is cut in the spring of the year. Young trees, twelve years old, are those which are preferred by the tanner. It is said, in fact, that the older a tree becomes after twelve years, the less tannic acid the bark will yield; so that trees twelve years old are the best trees for the tanner. It is stated that in mild springs the tannic acid is very much larger than in wet and cold springs. It is also stated that the yield of the tannic acid is very much larger if the bark is obtained during the time that the spring sap is ascending. Sometimes the tree is cut down, and I think it is the most humane way: for of all the melancholy sights which can be presented to one's eye in the country, there is scarcely any more pitiful than the ghost of the stripped oak-tree standing bleached and bare. The giant of the forest, thus exposed, soon dies; for trees cannot live without their bark. Besides oak-bark, two sorts of acorns are used in tanning,—the one called *valonia*, the other *camata*. Valonia, which is the largest, is the produce of the oak of the Levant (*Quercus*

Ægilops — Fig. 10). These acorns contain a very

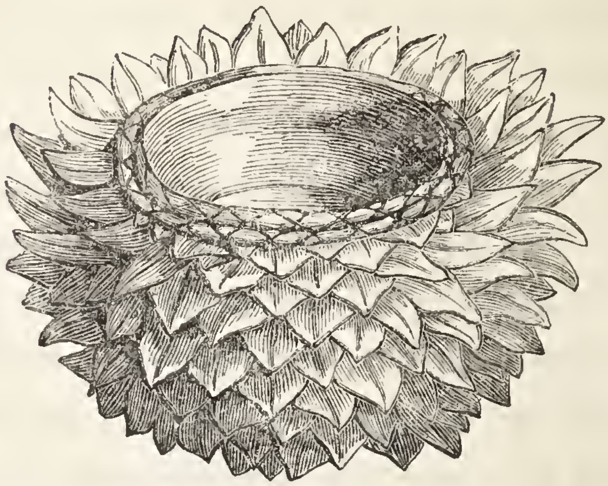


Fig. 10.—*Valonia.*

considerable quantity of tannic acid, and are more effective, weight for weight, than the oak-bark itself. Sir Humphry Davy calculated that four pounds of oak-bark ought to make one pound of leather; whilst two pounds of valonia will produce one pound of leather. The *camata* are smaller acorns. They are imported from Smyrna, and seem to be the produce of younger oaks of the same species. There is another substance which is used in making finer leathers, and this is the produce of a plant sometimes found in this country, but growing abundantly in the south of Europe, and known by the name of Sumach. There are two kinds; one the *Rhus coriaria,* used for tanning, and the other the *Rhus cotinus,* for dyeing (Fig. 11).

Fig. 11.—*Sumach.*

Sumach-bark generally contains from 16 to 20 per cent. of tannin; so that sumach is a better tanning substance than oak-bark. It is, however, more expensive, and there are certain drawbacks to its use. Unless leather has a certain light colour, it is not marketable, and leather-purchasers will not buy leather of a dark colour. The leather-maker is therefore hampered by this condition, and this has been the drawback upon the use of numerous tanning materials, and amongst others of this sumach.

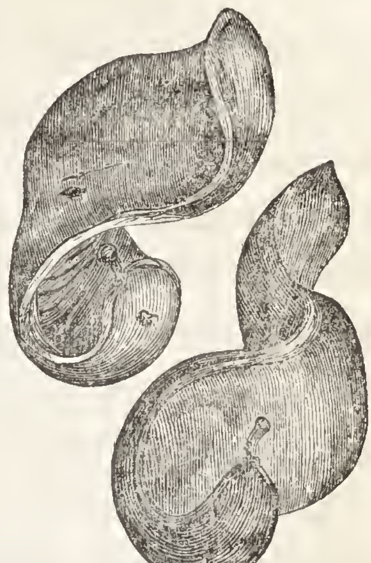


Fig. 12.—*Divi Divi.*

Another tanning material are the seeds of a leguminous plant (*Cæsalpinia*) like peas and beans, which are known in the market by the name of Divi Divi (Fig. 12). They are not so much employed as other things, because they contain large quantities of gallic acid. Then there are the fruits of a tree (*Terminalia*) looking like elongated plums, and these are called Myrobalans (Fig. 13); they contain a good deal of gallic acid as well as tannic acid, and can be employed by the dyer as well as the tanner, but still have the drawback of colouring the leather. Then there is a substance called Catechu, Cutch, or Terra Japonica, because, when first known, it was supposed to be an earth. It was used only as a medicine; but subsequently it has been found to contain 50 per

Fig. 13.
Myrobalans.

cent. of tannin. When it was found that tannin was the substance which formed leather, this substance, which had been used for two hundred years in medicine, was found to contain tannin, and now it is brought in very large quantities into this country. It is the produce of a tree growing in the East Indies called *Acacia Catechu.* The natives cut down the trees and cut them up into logs, and boil them, and evaporate the liquor by exposing it first to heat and then to the action of the sun to finish the evaporation. The latter part of this operation is principally superintended by women. The extract thus prepared, consists of 40 to 60 per cent. of tannic acid. Numerous varieties are brought to this country from various parts of the world besides the East Indies.

Mungo Park, during his travels, discovered an exudation from the trees (*Pterocarpus erinaceus*) of some parts of Africa, which he thought was a kind of dragon's-blood; but this substance, which is now called *kino,* is found to contain 70 per cent. of tannic acid. When tannic acid exudes from trees, it is now brought into the market under the name of kino.

A tree is used for tanning in the United States known as the hemlock spruce (*Abies canadensis*). It belongs to the pine tribe of plants, and is an excellent substitute for our oak-bark; but I fancy it colours the leather. The larch, another plant of the pine tribe, grows abundantly in Scotland, and is used in tanning; but the leather is a second-rate leather. I may here remark, that it is always worth the while of a manufacturer to make a second-rate article, provided he does not obtain by deception a first-rate price.

Willow-bark, ash-bark, and the bark of many other British forest trees, contain tannic acid, and have been employed for converting hides into leather. There is a bark brought from Australia, the mimosa or wattle bark (*Acacia*), which also contains tannic acid. These are very important facts for people to know in this country; for you know that we are none of us going to live the whole of our lives in England. We all contemplate one day emigrating, if the Reform Bill is not passed, or the paper duties repealed, or something else not done as we like, we make up our minds to emigrate; and large numbers of us do emigrate; and therefore it is of the very greatest consequence that we should take with us a knowledge of the arts and sciences, and the great principles on which our manufactures are founded, to our colonies. If we had done so at first, we should have earlier found gold and copper in Australia, and gutta percha in Hindostan; and many more colonial manufactures would have been established, and the trade products of our colonies would be much more numerous than they are now. Then, I say, let us educate our boys now, so that when they go out and see a thing likely to be useful, they may not pass by it as if they possessed no more sense or intelligence than the wild animals of the region. By the diffusion of a knowledge of such facts as these amongst our population, we shall contribute alike to the welfare of the colonist and the wealth of the mother country.

Many plants contain tannic acid that we should not think of using for the purpose of tanning leather. There

is the tea-plant. A quarter of all the tea we use is tannic acid; every pound of tea contains a quarter of a pound of tannic acid, although there is no fear of its turning the mucous membrane into leather; for whilst it is alive, the stomach will not submit to the process of tanning; yet tea is often a great offender of the stomach by reason of its tannic acid. I may mention that there are persons in India who chew catechu; and here is the betel-nut palm (Fig. 14), which yields the nuts

Fig. 14.—*Areca Catechu.*

containing tannic acid, which are cut up and chewed with a little lime and long pepper. It is thus used throughout India, and not only by Indians but by Europeans, who acquire the habit, and slily practise it even when they get back to England. The tannic

acid in the interior of the nut gives it a marbled appearance, and sometimes these nuts are made into buttons. Then there are a great number of medicines in the Materia Medica of the Pharmacopœia, all of which depend for their medical properties upon the tannic acid they contain. The old physicians had their long lists of substances, which they thought all had different properties, and which, when they came to be examined, were found to depend for their medical properties upon tannic acid. I suppose the doctors now prescribe tannic acid instead of the old plants from all parts of the world. If they do not, they ought.

There is no skin that is not composed in the way I have mentioned, having more or less the characteristics of the human skin. Human skin may be tanned, but it resists tanning to the last, and requires much longer treatment than other skins. The hide of the iguana, and the hides of whales, hippopotamuses, and other creatures, have been sometimes submitted to the process of tanning; but these do not come into the regular business of the tanner.

One of the most important articles of this business are horses' hides, from America. You know that throughout the Pampas of America there are men constantly employed in horse-hunting, from which we get tallow, skins, and bones—no part being lost. Those skins come to us dried or preserved in salt—not only horses' hides, but all other kinds of hides: ox-hides and sheep-skins, and so on, can be imported in this way. Then we have ox-hides, which are employed for the soles of shoes and for harness. Horse-hides are used principally for ladies' shoes; while cow-hides are used

for soles. Then the calf-skin is employed for making softer leather, which is used for the upper parts of leather shoes. Sheep-skins are used for making what are called chamois and morocco leathers. Lamb-skins are employed principally for making gloves. Then we have deer-skin, used for the finer kinds of morocco leather, for bookbinding and other ornamental purposes. The calf-skin used for making the upper-leathers of boots and shoes is dyed on the outside by means of the sulphate of iron. Goat-skin is used for morocco leather. Many of these skins are split, and are then called "skivers," which are used for a variety of purposes where thin leather is required. The goat-skin is used in various parts of the world for making bottles; such bottles are used in the East for carrying water on the backs of camels; they are similar to those mentioned in Scripture, where our Saviour speaks of not putting new wine into old bottles, lest the bottles break, and of putting new wine into new bottles, and both are preserved. To understand the reference, you must recollect that it is to this kind of bottles that allusion is made. Seal-skins are imported into this country in prodigious quantities; 600,000 seal-skins have been imported into this country in a single year. They are used for the purpose of making black enamelled leather, for making boots and shoes of a higher kind or quality; they are also employed for bags, dressing-cases, and a variety of ornamental things. This enamelled leather is made by the addition of a peculiar kind of varnish on the blackened surface. Then there are such skins as the hog-skin, which will not tan very well, because of the

large quantity of fat which it contains, and which resists the action of tannic acid; but it is employed extensively for making saddles. Then we have the buck and the doe-skin, for making gloves and gaiters; and the French catch rats very extensively, and make use of them for converting their skins into leather. If you are anxious to avoid the fact of appearing in a ball-room with rat-skin gloves, you may know them from other skins by the fact, that sometimes, in preparing the gloves, they leave a hair or two upon the surface of the skin, which has not been cut off, and by putting these under the microscope, you can, by the peculiarity of the hair, detect the kind of skin used. Then, you see, it is not one kind of skin alone that can be employed in making leather, but every kind; for there is none that does not submit to the action of this tannic acid.

With regard to the preparation of the skins for tanning, the processes are more mechanical than chemical. It certainly looks at first sight a remarkable operation by which these pieces of skin are converted into leather. The one substance so elastic, so durable, and the other so liable to decay. Skins are called by various names. The tanner does not speak of all his materials as "skins;" he applies that term technically. Small skins, such as those of calves, dogs, rats, cats, and mice, he calls "skins;" but when he makes leather from the full-grown ox, he calls it a "hide," or from the two-year-old animal, a "kip;" and thus he divides them: and it is a practical difference, for he treats them in a different way. When the skins are salted, they are put into water; but when they are dried and not salted, they

are also put into water, which, were they left, would in the course of time render them extremely unpleasant. You may have seen a dead dog in the Serpentine. If you rub his back with a stick, you tear off the hair. The layers of the epidermis are easily decomposed in the water, and there is a tendency in them to a putrefactive change. Sometimes there is no other preparation than putrefaction, but generally, the softening is produced by a process of liming, which assists in carrying off the hair and the epidermis. I say liming, because it is the process most in use in this country; but sulphuric acid, acetic acid, all sorts of garbage, and the refuse of our swill-tubs, which produce an acid by decomposition, may be used in assisting to get rid of the hair.

When the epidermis directly under the skin is got rid of, the subcutaneous adipose tissue, which retards the action of the tannic acid, must be also scraped away. After these processes the application of the tannic acid comes. The skins are placed in contact with the barks or substances containing tannic acid, and there are two ways of applying them—dry and wet. If dry, a quantity of spent bark is taken, and some fresh bark is placed upon it; and then the hide, then some fresh bark, and then a hide, and so on, until at last, a quantity of water is put in, and the hide is left to the action of the tannic acid.

Then there is a way of putting the hide directly into the tan-pit. A cold solution of tannic acid is employed, and you put the hide into that sometimes for eighteen months or two years; and the longer the process goes on, the better for those who buy the leather. This is

a long process, and it is only persons who can afford to wait for a return for their money for two years, who can engage in such a trade.

Various processes have been recently introduced for facilitating the converting of hides into leather. Numerous patents have been taken out to hasten the passage of tannic acid through the pores of the leather —but then it turned out that these leathers did not wear so well, so that the old tanner has got the better of the young tanner: but the new processes are still going on contending with the old; and you will find in Leadenhall Market that leathers are tanned in all sorts of ways. One of the last new processes I would mention, is that employed by Mr. Squire, of Warrington. Large wooden cylinders are erected, and into these wooden cylinders the hides are introduced; a quantity of warm infusion of tannic acid is then put in, and the cylinders are turned round rapidly, so that the hides are beaten about in the midst of a quantity of warm infusion of tannic acid. Now, here you have combined three things which are necessary. In the first place, there is no doubt that warmth, when it does not reduce the quality of the leather, is a thing which hastens the action of the tannic acid on the gelatinous hide. It is possible that the warmth may convert the gelatinous substance into gelatine, and that the tanno-gelatine thus formed may not be so durable as the leather made cold; but there is no doubt about its facilitating the process. Then, again, there is the constant agitation, which effects a more rapid union than the quiet lying in the tan-pit, and which is certainly a clear gain. Then I told you

just now that the tannic acid was converted into gallic acid by exposure to atmospheric air. Here you get rid of that action. But I do not know whether this is a good speculation, or whether the leather fetches as high a price; but I have been informed that the leather is as good as that obtained by the old process.

After the tanning, some leathers are curried. This consists in first shaving the skin to the required thickness by a knife peculiarly made for the purpose; after that it is covered with cod-liver oil and tallow, technically called "dubbing," and hung up to dry; after which it is finished off with pumice-stone and various other proceedings. Those parts which are used for soles are not curried. Then there are various operations afterwards carried on; such as dyeing, enamelling, and so on. These are not very complicated. Split leathers are dyed; and for this purpose they use cochineal for red, iron for black; and other substances which dye wool will dye leather.

Leather can be made without tannic acid. There are two substances which will effect this change in leather; one is alum, and the other is oil. Alum is formed of sulphuric acid, potash, and alumina. The skin is immersed in salt, and salt is chloride of sodium. Now, by the introduction of the skin into the alum with the salt, a chloride of aluminium is produced, and this substance is insoluble; the consequence is, that you get the leather of a softer and as durable character as when made by tannic acid.

So also leather can be made with oil. It is known by the name of chamois and buff leather. The chamois skin is not always used; for sheep, deer, ox, and other

skins are employed for this purpose. This leather is prepared much in the same way to begin with as for tanning, by taking off the hair and fat, and then oil takes the place of tannic acid. You know we keep anchovies in oil, and olives in oil—we can keep anything in oil; and thus skin is thoroughly impregnated with oil to make it keep, and afterwards washed with alkali, to remove the greasy condition.

Mr. Preller, of Bermondsey, by his process, prepares the skins first by the introduction of starch, gluten, albumen, and things of that kind, and afterwards finishes them by the oil process. The skin is fulled by means of machines, such as are used for fulling cloth. Sometimes they are put into large tubs, and rubbed by hand. Sometimes men get into the tub, jump, and knock them about with their naked feet. Sometimes they are prepared with the hair on—two are sewed together, so that the hair of each is in contact with the other. The prepared skins are called leather, although they have never been tanned.

Russian leather, which smells so pleasantly, is prepared in the usual way, and then tanned with willow bark; it is put into a solution of red sandal-wood, and then, while the process of currying is going on, the oil from the birch is said to be introduced, but I believe this oil of birch is scented by the sandal-wood.

I cannot now go into detail about the application of leather. There is one remarkable application of leather, in which everything else has been tried and failed, and that is the making of mill-bands. These are used for making those revolutions in the wheels of our machinery, without which the manufacturing in-

dustry of this country would come to a stand-still. Then we have the harness-maker's shop, with saddles and collars, and all the apparatus for the management of the horse, made of leather. Then there is the cabinet-maker, who covers chairs and sofas with leather. Railway-carriage seats are covered with leather. Then there is the beautiful ornamental leather-work, carried on so successfully in this country. The leather is stamped and made into a variety of forms to imitate every kind of carving. Another great use of leather is the making of gloves :—

"Kid and lamb-skins are those chiefly used, but buck and doe-skins are also employed for the stronger kinds. At Limerick they are notable for making what are called chicken-gloves, from the skins of very young calves, and packing each pair inside a walnut-shell, fastened with a little silk riband, which are retailed at 5*s.* each pair, thus enveloped. It is estimated that 12,000,000 pairs of gloves are annually made in the United Kingdom, besides which we import about 4,000,000 pairs annually. There is an old proverb, that a good glove should be of Spanish leather, cut in France, and sewn in England.

"The average quantity of leather gloves made in this country has been estimated at 12,000,000 pairs annually, which, at an average value of 2*s.* per pair, amounts to £1,200,000. In addition to this, we received, in 1856, nearly 4,000,000 pairs from France. Although we are well supplied with the skins of animals at home, having plenty of sheep and lambs, nevertheless large quantities are imported, and used chiefly in the manufacture of gloves.

"In 1855 we imported the following :—

	Number.	Value.
Goat	503,918	£44,071
Kid..................	695,859	100,012
Lamb	828,031	38,682
Sheep	977,970	51,211
	3,025,778	£233,976

"Therefore, as 120 skins average 216 pairs, it follows (supposing all the imports are worked into gloves) that upwards of 5,446,000 pairs of gloves are manufactured in England from foreign skins.

"In 1855 the leather gloves imported for home consumption amounted to 3,380,648 pairs, valued at £227,000; and yet our home trade supports a vast number of men, women, and children, who are employed in their manufacture; the cutting-out, sewing, binding, setting on the buttons, linings, and trimmings in large manufactories, like that of Dent's at Worcester, affording as many different branches of occupation. An instrument for glove-making has been invented, which enables the sewer to effect the utmost accuracy in this process.

"The continental glove-trade chiefly centres in Paris. The French glove-makers are said to derive a handsome profit from the use of rat-skins taken in the Paris sewers, and from the large common pound, where offal and carcasses are thrown. In 1851 gloves to the amount of £263,000 were imported into the United States.

"Beaver gloves were formerly made at Worcester and Hereford, of leather dressed with oil. The various descriptions of leathers consist of tawed or alumed leather gloves, of which kid is an example; real kid; imitation kid, made of lamb-skin; deer-skin gloves, and military gloves.

"Formerly English skins were wholly used, but now Spanish, Italian, and German lamb-skins are the principal kinds employed."

Skins are split and made into vellum and parchment. On parchment we inscribe our deeds, and on vellum all our great state documents. There are in the South Kensington Museum writings dated 1237, 1325, 1428, and 1521; showing how well these skins are adapted for receiving and retaining the important records of the history of our property and institutions. There is a curious imitation of this parchment lately introduced by my friend Mr. Warren De la Rue; it is made out of common paper. A sheet of blotting-paper—unsized paper—is dipped into oil of vitriol and water; the consequence is, that it acquires all the

properties of parchment, and can be used for many of the same purposes.

There are many other purposes to which leather is applied, and which will occur to you all. The readiness with which it may be cut and stamped has led to its extensive use in the fine arts, and beautifully-formed objects, such as birds, plants, &c., have been made out of this material. The manufacture of baskets, reticules, picture-frames, and other articles of use in leather, has lately become fashionable work for young ladies; in fact, wherever elasticity, durability, warmth, and imperviousness to water are required, there leather may be used; and when we remember the number of its applications, we feel more inclined to regard with complacence the declaration of the tanner in the fable, that, after all, "there is nothing like leather."

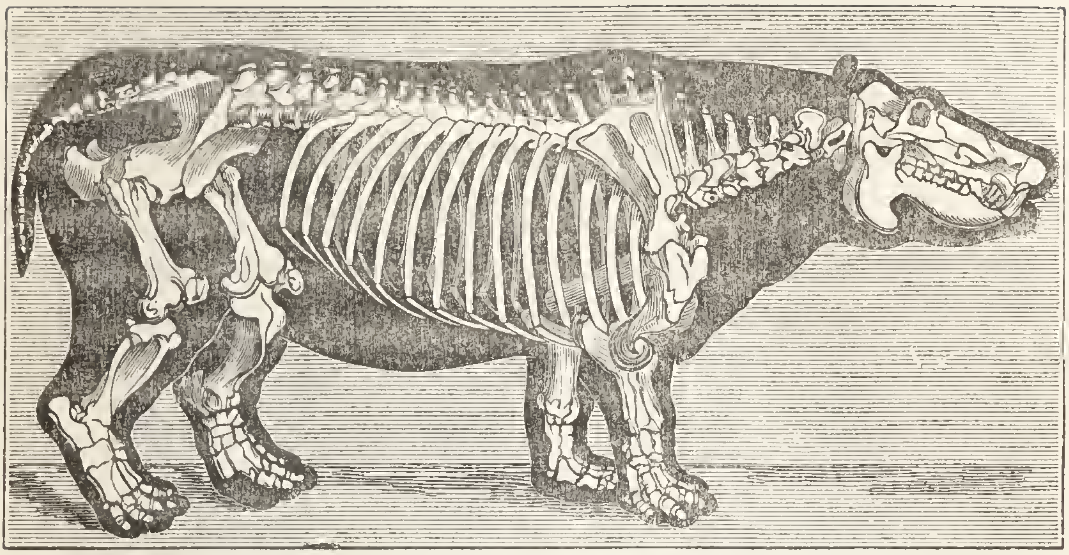


Fig. 1.

ON BONE.

Passing on from the skin of animals and its appendages, I now wish to draw your attention to those solid internal parts of the animal which we call its skeleton. The skeleton is composed of bones, which being solid, white, and durable, are used for many purposes in the arts. We find these bones which are thus used in the arts in all the classes of vertebrate animals. There are fewer used perhaps for the manufacture of solid articles of use from fish than from any other class; but, wherever animals have bones, there the same chemical constituents are found, and these constituents can be employed for a variety of purposes. It would be extremely interesting here, would space permit, to show you the contrast between the ex-

ternal skeletons of the lower animals — such as the shell-fish, the crabs, lobsters, and insects—and the skeletons of the higher animals. I might show you that just as the skeletons of insects are composed of a series of rings, the first of which develop jaws and antennæ, and the next legs and wings, so a common type develops the various parts of the skeleton of the vertebrata. Here I have (Fig. 2) what Professor Owen calls the archetype of the vertebrate skeleton, and this supposes that a large number of pieces of this kind are united together. From the modification by growth of parts like these, we have as a result all the various forms of the vertebrate skeleton. The upper portions surrounding the part marked N form the spinal canal and the skull, which protect the spinal cord and the brain. The lower and lateral portions surrounding the space marked H form the ribs and thoracic cavity, containing the lungs, heart, and stomach; whilst the projecting lateral portions are developed into the upper and lower extremities.

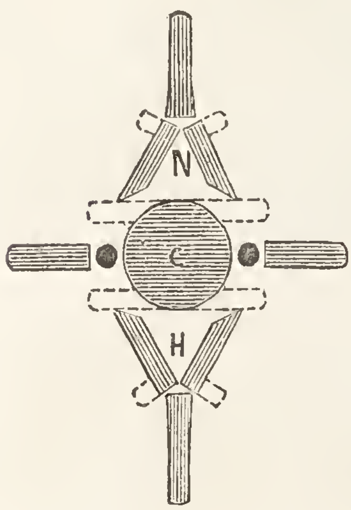


Fig. 2.
Archetype of Vertebrate Skeleton.

Now, the growth of this skeleton proceeds very much in the same way as the growth of hard parts both in plants and animals. Those who have worked with the microscope will recollect having seen in all parts of plants, in the hard part of the ivory-nut, and the hard coat of pepper-husks, a little space in the centre of the cells something like an insect with a number of legs: when-

ever hard parts are formed, cells of this kind are produced. Then we pass on to animals — the skins of insects, crabs, and lobsters, present the same cells,—so also the scales of fish; and now, when we come to the hard internal skeleton of vertebrate animals, we find the same kind of cells. They look like rows of insects running one after another. Bones are made up of this kind of cellular structure. Bones are of various kinds,—flat and round, and long and square. For commercial purposes this is of importance. The external surface of a bone is hard, whilst the internal is soft, and is called cancellated. But whether hard or soft, we get the same general structure.

Now, if we take a bone and look at its surface, we find that there are a number of rather large holes; and if you make a section of it, you will find these holes lead to canals, which are called Haversian canals, after Clopton Havers, their discoverer. These canals are represented in Figs. 3 and 4. Now, they vary

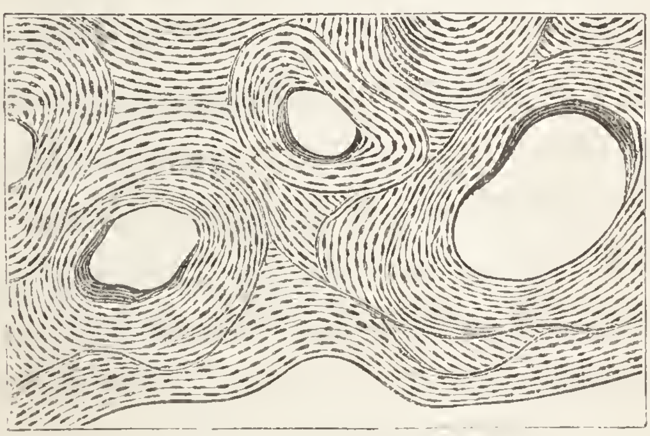


Fig. 3.—Transverse Section of Bone, with Haversian Canals.

much in size: they are smaller in the harder parts of bone, and larger in the softer parts; but whether large or small, they are always surrounded with a series of

lamellæ, which are made up of a number of little bodies

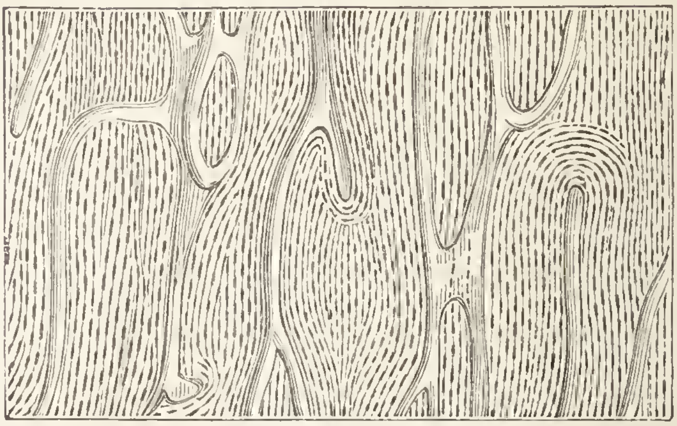


Fig. 4.—Longitudinal Section of Bone, with Haversian Canals.

represented by these black spots (Fig. 5), which are

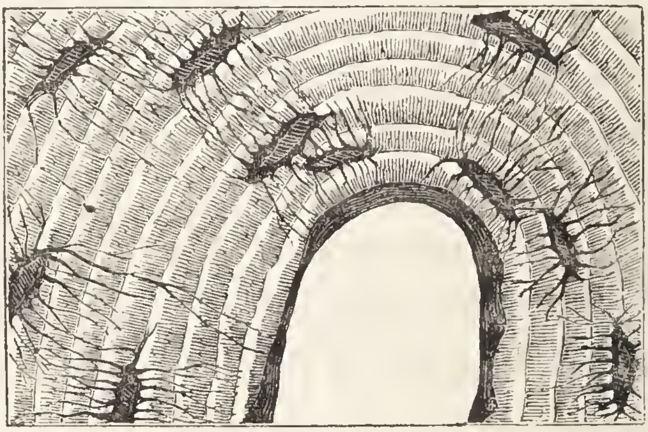


Fig. 5.—Lacunæ and Canaliculi of Bone.

called by the anatomists *lacunæ,* and sometimes bone-corpuscles; these names show the difficulty of ascertaining whether they are hollow or solid. I think the universal conviction now is that they are hollow. Passing on from each side we have little canals, which are called *canaliculi.* They communicate one with the other. Now, between these little cells there is everywhere a common structure (Fig. 6), and under a high power of the microscope this structure presents minute six-sided bodies. Now, these little bodies are particles of phosphate of lime, which constitute the

brickwork, as it were, of the walls of these curiously-shaped cells.

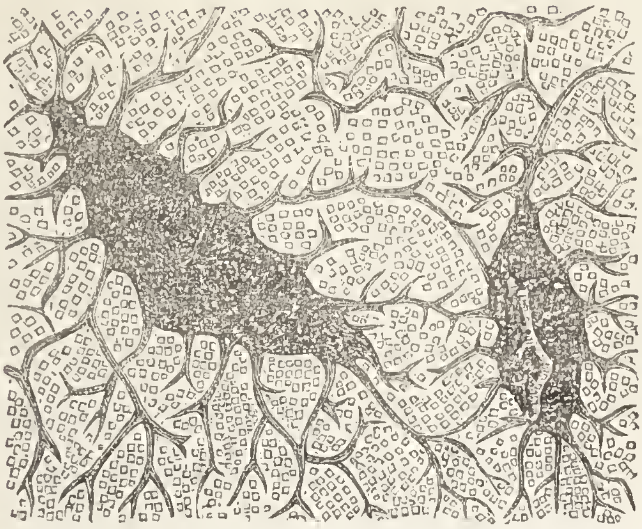


Fig. 6.—Crystals of Phosphate of Lime in Bone.

The bones are finished off with two structures, which are not immediately osseous. There is a membrane covering them, which is a fibrous membrane, called the *periosteum.* In the interior they are hollow, and contain what is called marrow. This hollowness is of considerable utility in the manufacture of the bones. The little bone-cells, curiously enough, differ in size in almost every family of animals; so that a person well informed with regard to the structure of bone under the microscope, may discover whether a minute section, hardly perceptible to the naked eye, belonged to a man, to a mammal, a bird, or a fish. We are indebted to Professor Quekett, of the College of Surgeons, now President of the Microscopical Society of London, for having pointed out a remarkable fact with regard to the bone-cells; and that is, that they correspond in size with the size of the blood-globules. You know that animals contain in their blood, cells called blood-cells, which vary in size in different animals. In

the human being the globules are the 3,500th part of an inch in diameter, and in the bones of the human being the bone-cells are the 2,000th of an inch in diameter; in birds they are about the 5,000th of an inch in diameter, whilst the blood-globules are the 6,000th; in reptiles the blood-cells are not more than the seven-hundredth or a thousandth part of an inch in diameter, and the bone-cells not more than the five-hundredth or a thousandth. There is, then, a general correspondence between the size of these two sets of cells; but there are numerous exceptions, and the statement must only be looked upon as expressive of a general relation.

Having said thus much with regard to the microscopical structure of bone, let me now call your attention to its chemical composition. The following is the general composition of bone—not of human bones or ox bones in particular, but of bone generally:—Organic matter, 40 parts; phosphate of lime, 50 parts; carbonate of lime, 8 parts; fluoride of calcium, 1 part; other salts, 1 part. You will find that the gelatine, the part which composes the organic tissue, and the fat, which constitutes the marrow, constitute the 40 parts; while the substance known as bone-earth (phosphate of lime) consists of 50 parts; and then we have common chalk (carbonate of lime) in our bones, and the bones of all the higher animals, in the proportion of 8 per cent.; and we have also a little Derbyshire spar (fluoride of calcium), 1 per cent. Why it is there we do not know; but there it is, and it is very generally present in the higher animals. Then there are sulphates of soda, potash, and magnesia; other salts about 1 part in 100.

I shall now proceed to point out the properties of these constituents, because the properties of these substances are those which render the bone so valuable in the arts. There are at least seven purposes to which these substances are applied in the arts, and each one of those has some reference to the composition of bone.

Now, first with regard to gelatine, I will not further describe it in this lecture than to remind you that it is that material of which I spoke to you at first as distinguishing the animal from the vegetable kingdom—as that material which constitutes the great bulk of the skin of animals, which, when placed in contact with tannic acid, forms an insoluble substance,—a fact which lies at the foundation of the manufacture of leather—as that substance which, when boiled out of calves' heads and calves' feet, constitutes so delicious an addition to the dinner-table,—which, when boiled down from the clippings of bones and hides, is converted into glue, or made into size, by which we bind our books, or put a hundred articles of use together. I need not describe it further, but you see how important a substance this is.

Now, taking the fat next, we shall find that it also constitutes an important element in the composition of bone. It is bad economy to throw bones away. There are persons in London willing and anxious to purchase those bones, not so much for the phosphate of lime and gelatine, as for the fat, which is applied to making candles and soap. Now, the fat exists in the hollow parts of the bones, in what is called the marrow, and very generally throughout the structure of the bone, in its cavities.

The phosphate of lime is a substance whose composition is very simple; one of its principal elements is phosphorus, which is so inflammable that we have to keep it in water to prevent its taking fire: this, combined with oxygen gas, forms an acid which is called phosphoric acid. This acid unites with lime to constitute phosphate of lime. We have phosphate of lime, as it is obtained from rocks which lie at the very foundation of the earth. This is the first source of phosphate of lime before it comes into bones. First it is dissolved by carbonic acid gas, in water, then picked up by the delicate blades of plants, then introduced into the stomachs of animals, then deposited in their bones. Even when thrown out by them, it is carefully collected by man, and thrown on to the fields where he grows his cereal plants.

The carbonate of lime is not an uninteresting constituent of bones: we can generally get evidence of its existence by pouring upon a crushed bone some sulphuric acid, which produces an effervescence. There is no effervescence from phosphate of lime, but you get it from carbonate of lime: eight parts in one hundred of our bones are carbonate of lime. There is an interesting relation between carbonate and phosphate of lime, as being the substances which chiefly contribute to the formation of the skeletons of the whole animal kingdom. In the skeleton of a coral we have a mass of carbonate of lime. In insects, crabs, and lobsters, we find a little phosphate of lime coming in; as we go higher, the phosphate of lime increases, and the carbonate of lime decreases, until we come to man, who possesses the largest amount of phosphate of

lime; but the carbonate has not been wholly dispossessed. This coming-in of phosphate of lime and going-out of carbonate of lime may be represented by this diagram :—

Man.—Vertebrate.

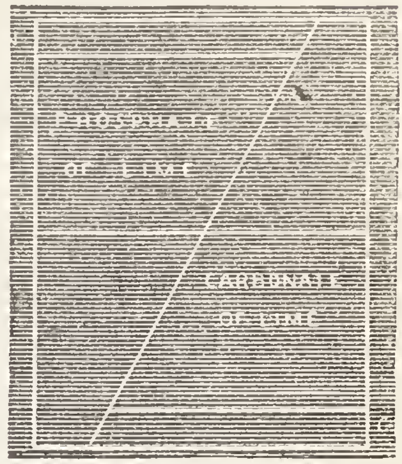


Fig. 7.

Corals.—Invertebrate.

Of course this diagram gives only an approximation to the real distribution of the salts of lime in the skeletons of the animal world. The phosphate of lime goes on decreasing as the animal is lower in the scale, until at last we find scarcely any phosphate of lime and large quantities of carbonate of lime.

Fluoride of calcium is interesting as occurring in human bones, as well as the bones of lower animals; and a very curious fact has occurred in connection with its presence, and that is, that a large number of the fossil bones of elephants and other creatures that have recently been brought from the Sivalik Hills, in the Himalaya, by Dr. Falconer and Sir Thomas Cautley, are found to contain, not phosphate of lime or carbonate of lime, but fluoride of calcium. Thus it has been supposed by some, that animals really formed their bones of fluoride of calcium, while others have conjectured that bones, whilst lying in the earth, had changed their phosphate of lime into fluoride of calcium. In order to explain this phenomenon more satisfactorily, I would call your attention to the fact, that carbonate of lime is insoluble in water; but if water becomes charged with carbonic acid gas, as it does when passing through

the atmosphere, it has the power of dissolving carbonate of lime and also phosphate of lime. We have no other means of understanding how it is that plants could take up phosphate of lime unless it was dissolved, and it appears that phosphate of lime dissolves in water containing carbonic acid gas. Fluoride of calcium, or Derbyshire spar, also dissolves in water containing carbonic acid gas, but not with equal facility. Carbonate of lime dissolves much more freely than phosphate, and phosphate more freely than fluoride: hence it comes to pass that water holding fluoride of calcium in solution, passing over a substance containing phosphate of lime, would prefer taking up the phosphate to holding the fluoride, and would drop the one and take up the other. Thus you see how elephants' bones, containing the phosphate, might lose it and have fluoride deposited in its stead. In the secondary and tertiary rocks of the earth, we have deposits of phosphate of lime, under the name of coprolites. They are collected and sent to the agriculturists, and used for manure. How do these deposits occur? Why, water containing carbonic acid gas and phosphate of lime, has percolated through the strata containing these bodies, and carried away the carbonate of lime, and left behind them this precious phosphate of lime for the preservation of our lives and the increase of our race.

Then, besides phosphate and carbonate of lime and fluoride of calcium, we have certain salts whose presence does not render the bone more useful in the arts. There is magnesia, which must be there, and disease takes place when it is absent; and so with the other salts.

But we may leave these and look now to the uses to which the other substances are applied.

In the first Lecture I mentioned to you that we might make a class of those things which were applied to the production of solid articles of use: and all solid substances are applied to some useful purpose. For instance, shells are used for forming the handles of knives; wood is also used for the same purpose; so are bones and ivory. There are a great number of uses of this kind to which bone is applied. There is a very useful application of bone in the production of a very common article of use—buttons. These buttons are produced in prodigious quantities in the towns of Birmingham and Sheffield, and they are sent out into the world in ton-loads from year to year. They are so cheap that some of them are sold at the rate of twelve dozen for a groat, wholesale. There is no material from which buttons can be made so cheap—and every one knows their uses, and how valuable they must be wherever man is sufficiently civilized to wear clothes. Then there are bone-carvings, card-cases, combs, brushes, parasol-handles, book-holders, knives and forks, thimbles, counters, rings, and other articles too numerous to mention. In the manufacture of these articles the shavings and sawdust are not thrown away. These are collected and sold for various purposes in the arts. One purchases the bone-dust and shavings for the purpose of manufacturing size; another buys them for making a supposed nutritious article of diet. The roughest parts are gathered up and are sent off to the glue-makers and manure-manufacturers; but not a particle is lost.

I stated that phosphate of lime was composed of a certain quantity of phosphorus and oxygen and calcium. Now, although this phosphate of lime has been known for a long time under the name of *Apatite*, yet this mineral is not the substance from which we obtain phosphorus for the arts. After the gelatine has been boiled out of bones, the phosphate of lime is left, and this phosphate of lime is treated with sulphuric acid, and the sulphuric acid withdraws the lime from the phosphate, and we have left in the vessel phosphoric acid. This is mixed with charcoal in a retort. The charcoal combines with the oxygen, forming carbonic acid gas, and phosphorus is distilled. Thus it is obtained for the chemist. He uses it to illustrate a variety of processes. It enables him to perform most brilliant experiments, and by it he can show the composition of the atmosphere, the nature of combustion, and a variety of other effects which could not be so well effected by other agents. Its great use in the arts is for the manufacture of lucifer matches.

Many of you can recollect how your grandfathers and grandmothers, after much labour and patience, obtained a light by means of a flint-and-steel and box with tinder, and a match with sulphur; what a blowing there was, and what tears were often shed before a fire was lighted of a morning, and frequently of a summer evening before a candle could be seen on the table; but now all this has gone by. I can remember, when I was a lad, standing in the market-place of my native town, seeing a man come down the steps of the Shire-Hall with a tray full of little boxes of matches, which we all thought wonderful. He said he could

not sell them because the magistrates considered them dangerous. These were the first lucifers I ever saw. The magistrates forbade the man to sell them, as they considered them likely to encourage the dangerous practices of ill-disposed persons who were signing themselves by the name of "Swing." But mankind has been wiser than the magistrates, and has trusted to good sense and intelligence, and nobody feels that the world is the worse for lucifer matches.

In making lucifer matches the phosphorus is combined with one of two things—either chlorate of potash or nitrate of potash. One or other of these substances is mixed with the phosphorus and some sulphur, and having been brought to the melting-point, little pieces of wax or wood are dipped into it. Thus the phosphorus is brought in contact with a supporter of combustion in the oxygen contained in either the chlorate of potash or nitre. Although the nitrate of potash contains more oxygen for its bulk, as the atomic number of chlorine is thirty-six and that of nitrogen only fourteen, yet the chlorate gives off its oxygen gas more freely. Quiet lucifer matches are of foreign manufacture, and are made with nitrate of potash. The chlorate of potash makes more noise in giving up its oxygen. It is generally employed in the English matches.

Now, there are two kinds of phosphorus, and one of these does not require to be kept in water. The piece of phosphorus which I now show you was exhibited at the Great Exhibition in 1851, and here it has stood under this glass case ever since. It is called red phosphorus, and just in proportion to the heat to which this body is exposed before it cools down, will

be its tendency to take fire in the air. This was discovered by Schrötter. Now, the manufacture of lucifer matches is attended with a dreadful drawback to the persons engaged. Whilst heating the phosphorus, the fumes rise into the air, and they are taken into the system; and, although the action is imperfectly understood, yet there can be no doubt that the agency of the phosphorus is to act upon the bone and the solid tissues of the body, and to produce severe and fatal disease. It was hoped that a remedy had been found for this in the red phosphorus; but I understand that it is not sufficiently inflammable, and on that account is very little employed in the present day. I may, however, state that lucifer matches are made in France which only light by being brought in contact with a surface containing red phosphorus. This substance is introduced upon the rubber of the box, and thus the matches are prepared without the aid of the yellow or more inflammable phosphorus. Should that manufacture be introduced into England, I should say it would be worth a little inconvenience and trouble to encourage it, in order to get rid of an article which is really produced at the cost of the lives of our fellow-creatures.

Passing on from the manufacture of phosphorus and lucifer matches, I would call your attention to what I said with regard to the presence of fat in bones. I shall have more particularly in the next Lecture to speak of the action of fat, first upon the alkalies producing those useful substances called soaps, and then in the manufacture of candles. I would remark here, then, that bones, when picked from the streets when

perfectly useless for the manufacturer of buttons or the smallest possible article of a solid kind, can yet be usefully boiled down for the gelatine, on the one hand, and the fat on the other.

Then, when bones have been boiled, and they have yielded up their gelatine and have given up the fat they contain, there is still enough animal matter left to render it a very useful material in the formation of animal charcoal. Perhaps one of the greatest benefits those who live in the neighbourhood of bone-boileries have experienced, has been the conversion of boiled bone into charcoal. It was the practice formerly to send these bones to the manure-manufacturer, in order to be distributed over the soil; but this process was always attended with states of decomposition which rendered the bones very offensive. If you take a bone and expose it a few days, the gelatine is decomposed, and carbonate of ammonia, called smelling-salts, with other compounds, are formed; and some persons would hardly be satisfied with calling it an ammoniacal, but they would call it a demoniacal odour, on account of its intensely disagreeable smell. But the bones now, instead of being sent into the country as manure, are burnt, and thus converted into animal charcoal. This charcoal must always contain large quantities of phosphate of lime. At first sight one would have thought that the presence of phosphate of lime would have been a drawback; but it has been found that it is not so. For almost every purpose for which any charcoal is used, that from bones is found to be by far the most effective; so that now the manufacturers of filters and

sugar-refiners use bone charcoal; and we find that a large consumption of the waste bone from the bone-boilers takes place in sugar-refineries. Bones burnt in this way, after the glue and size and fat have been obtained from them, are now producing as much as £16 or £17 per ton in the market.

There is yet another use of bones, which has led to results which can hardly be appreciated or estimated by mere figures, but must really be valued in the rise of manufactures, in the multiplying of food, and in the increase of happy families in our country.

Phosphate of lime is necessary to our bones. It is therefore necessary that we should eat food containing phosphate of lime. If we do not get this phosphate of lime, our bones soften—we become mere gelatinous masses, and perish. We can get this food from the animal kingdom: beef and mutton contain phosphate of lime. But if phosphate of lime is necessary to the existence of these creatures, where are they to get it? From the grass and the corn of the field. And we also must not depend upon the animal kingdom. We must obtain it from our vegetable food—in our wheat and other vegetable substances. We know that the farmer grows a rotation of crops, and every now and then he renews the fertility of the soil by manures, because the plant exhausts the soil of the phosphate of lime. Therefore, wherever there is phosphate of lime to be found, either in the refuse of the bone manufacturer, or any other place, it becomes valuable as manure; and it is the discovery of this fact which has led to the use of a variety of substances as manures formerly unknown. The farmer now uses crushed

bones and other substances containing phosphate of lime. But we have also mineral sources of this phosphate of lime. We get from Sweden and other places large quantities of the mineral apatite. It exists in the province of Estremadura, in Spain, and might be made of more value to that country than all the gold she obtained in her conquests in the New World.

Then there are the substances called *Coprolites,* found on the coast of Essex and Suffolk, and the Greensand and Wealden formations. They have been formed out of the phosphate of lime which was once contained in the bodies of gigantic whales, reptiles, and fishes. These coprolites are not the excretions of these animals, but they are nodules of phosphate of lime, which have been formed by layers deposited from water which first washed and then held in solution the phosphate of lime from the skeletons of these huge creatures. What a grand view this opens up to us of the relation of created things. Thus, the very particles of matter that compose our bodies to-day, may have formerly been present with the ichthyosaurus in his piscine feasts in the depths of a Liassic ocean, or rolling about in the body of some whale that lived in the sea which deposited the clay on which our house now stands.

Before these forms of phosphates are used as manures, they are reduced to the condition of a super-phosphate. This substance is made in the simplest way. These coprolites, or the apatite, are ground down, and are then treated with sulphuric acid enough to take away one portion of the phosphoric acid. By taking away a part of the lime by the sulphuric acid, we leave a

bi-phosphate, which is the form in which plants take it up. Hence the manufacture of super-phosphate of lime; and in country places large manufactories of this substance are springing up. Just wend your way to the eastern coast of Suffolk. You will see there large loads of sulphur and nitrate of soda, and these are used for the purpose of making sulphuric acid, which, being mixed with the coprolites, convert them into super-phosphate, for the purpose of manure. So much, then, for the form in which the phosphate is applied to the earth.

Another set of substances obtained from bones are ammoniacal salts. Ammonia consists of nitrogen and hydrogen, and it may be obtained from gelatine, or any decomposing animal matter. If you take any animal matter, as dead dogs, cats, mice, pigs, and so on, and put them into a retort, you will get not only nitrogen and hydrogen, but carbon and oxygen; and thus you may form carbonate of ammonia. By adding hydrochloric acid to these substances, you obtain hydrochlorate of ammonia, or sal-ammoniac.

I will now ask your attention whilst I speak of the nature of ivory. Ivory is a substance very much like bone; but, having a finer texture, it is more delicate in its appearance, and it has the power of enduring longer, and, therefore, of recompensing the labour of the artist, and commanding a higher price in the market: so that ivory is used much more extensively for works of art. It has always been a favourite material for carving. We find it used among the Chinese for this purpose. These people seem to think no labour too much to produce these curiously-carved articles. Their

ivory balls, carved one inside another from one piece of ivory, are marvels of patience, industry, and ingenuity; and most elaborate ornamentation is put upon ordinary things made of ivory; such as chessmen, cabinets, drinking-cups, and other things.

In order to enable you to understand the nature of ivory, I must speak of the structure of teeth generally; and I will first describe the construction of human teeth in illustration. Here is a human tooth—a canine tooth as it is called (Fig. 8). It consists of three parts —the upper outside part is called the *enamel*, and the inside part the *dentine*, and the lower outside part, which covers the fangs, the *cementum*. In the interior of the dentine is the pulp, which contains the delicate vessel and the nerves; and it is the exposure of this little nerve which gives us the pain called the toothache. Now, these teeth are connected in all the higher animals with the jaw; they sink down into the bone, and we thus distinguish the teeth of the mammalia more especially from those of the lower creatures, by the fact of their sinking down into the sockets of the jaw. They are called *neural* teeth, in contradistinction to the teeth of fish, which are called *dermal* teeth, and which grow upon the surface of the mucous membrane. Now, taking the gnawing teeth of the gnawing animals (*rodentia*), —as rabbits, hares, rats, and mice, we have two teeth projecting from the upper jaw, and two meet-

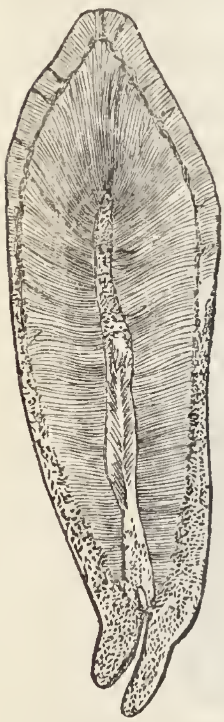


Fig. 8.

Section of Human Canine Tooth.

ing below. These teeth are formed with the hard enamel on the outer surface, and with the softer cement on the inner surface (Fig. 9); so that by the wearing away of the inside, the outer thinner layer projects, and the tooth is constantly kept sharp.

Fig. 9. *Tooth of Rodent.*

Then, in the ruminant and in the pachydermatous animals, we have an arrangement of the parts, such as is seen in the elephant's grinding-tooth. The plates of enamel are set in a mass of cementum. The latter giving way before the enamel, the consequence is, they are always kept rough. (Figs. 10, 11.) If you had a pave-

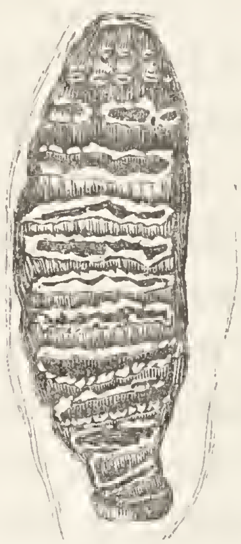


Fig. 10.—*Tooth of Asiatic Elephant.*

Fig. 11.—*Tooth of African Elephant.*

ment with a soft substance and a hard substance, you would constantly have a rough surface. This has been lately introduced by inserting wedges of iron into wood, just as the enamel is inserted into the cementum; and the wood continues wearing away. The chemical composition of the teeth is very like the chemical com-

position of bones; but I would draw your attention to the curious fact, that the enamel contains a very large or greater quantity of solid matter than the dentine or cementum. The enamel contains only 4 per cent. of organic matter against 40 per cent. in the bones, and 30 per cent. in the dentine and 39 in the cementum. A curious circumstance in the history of the teeth is, that the enamel contains a small quantity of silica or flint. It is only in small quantity, but it gives hardness to the enamel; and the want of this silica in the teeth is productive of a wearing away, and eventually a loss of the teeth altogether. Thanks to the art of the dentist, we can readily get new teeth: for this purpose he uses the teeth of the lower animals.

It is not, however, all teeth that can be used by the dentist, nor do all teeth yield what we call ivory. Those teeth to which we more particularly give the name of ivory are the tusks of the elephant; and the tusk of the elephant is so constructed that the whole of the outside of the tooth consists of dentine—of that matter which we find in the interior of the teeth of man; and this dentine is a substance which stands between the cementum and the enamel in its solidity and its chemical composition. It is on this account that we find it so useful in the arts; but the dentine of other animals is not so valuable as that of the elephant. We thus have the walrus, and the narwal, and other animals, which have dentine closely resembling the ivory of the elephant, and they serve the purposes of the dentist, but they are not generally used for ivory manufactures. The microscopic structure of the ivory of the elephant explains why it is so valuable as compared with others. If you

supposed the cells we saw in bones elongated, you yet would get a structure something like this (Fig. 12).

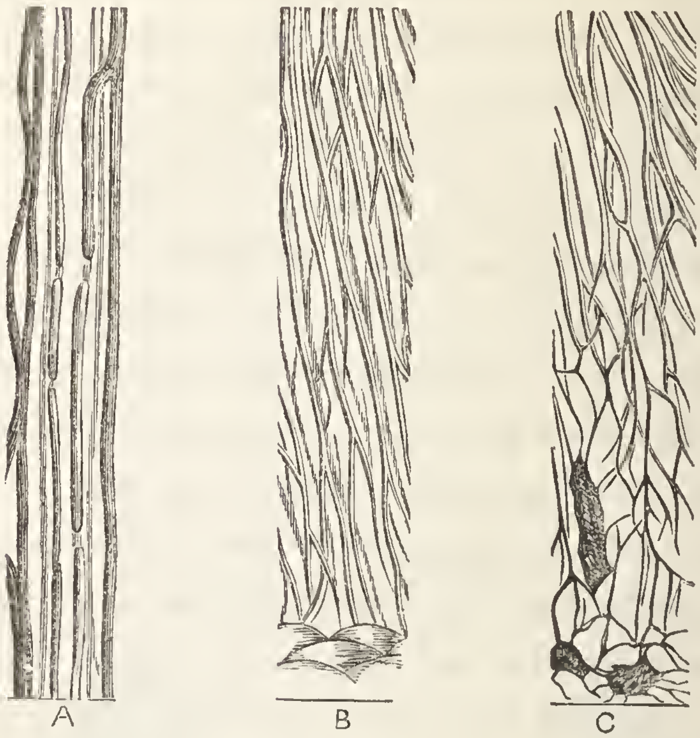


Fig. 12.

A. *Large Dentinal Tubes.* B. *Fine Dentinal Tubes.*
C. *Dentinal Tubes and Bone-cells.*

The little canals of the bone-cells are represented by these little stripes, which are really tubes. Now these tubes are not generally more than the ten thousandth part of an inch in diameter, and being closely packed together, constitute the structure of ivory. It is its dense character which gives it its superior value. The tubes are also curved, in ivory, which they are not in the case of other teeth; and this is another cause of the value of the ivory of the elephant.

Fine ivory is known by having no cracks or flaws either in the solid or in the hollow. Cracks in ivory are a serious detriment, and must be always particularly noticed. The elephant's tusks that are only

rather tapering in shape are most liked; very crooked teeth must be guarded against, as they cut up to great disadvantage. In many tusks there are marks about the centre which are called shots: they are caused by the bullets of the Africans, and flaw the ivory two or three inches round the ball, and considerably diminish the value. Broken-pointed tusks, or those with deep flaws, or otherwise damaged about the point, must be avoided. Tusks with large hollows are not at all liked, as there must inevitably be a great waste in cutting them up; in short, a fine tusk is known by being of a neat tapering shape, and a small hollow, free from cracks, with a fine, thin, clean coat, free from flaws, &c.: it is also transparent; which may be discovered by holding the point to a candle. The Gold-Coast ivory may generally be known by having a rough-hewn hole made near the end of the hollow; and this ivory is much esteemed.

The London dealers classify the tusks into the following sizes:—

Firsts, or those ranging from 70 to 90 lbs.			
Seconds, weighing about		56	lbs.
Thirds	,,	38	,,
Fourths	,,	28	,,
Fifths	,,	22	,,
Scrivelloes, all under		20	,,

The tusks and teeth of the elephant—the latter, for the sake of distinction, are termed grinders—are formed after the ordinary manner of the teeth of animals. The organism which converts the earthy constituents of the blood into cellular tissue and membrane, contributes in the same way to form the

teeth by the successive depositions of layer upon layer of the soft vascular pulp. The marks of these depositions, or laminæ, are clearly distinguishable in the longitudinal striæ of the section of a tooth. The tooth is hollow about half-way up, but a very small tubular cavity is visible throughout its entire length. This, sometimes called the nerve, is in reality the apex of successive formations in the process of growth. The grinders are seldom used in the arts. They are of a different texture, the laminæ more loosely combined and possessing a tendency to separate, which renders them unfit for nearly all useful purposes.

The greatest consumption of ivory is undoubtedly in connection with the cutlery trade. For these purposes alone about two hundred tons are annually used in Sheffield and Birmingham; and the ivory in nearly every instance is from India. The mode of manufacturing knife-handles is very simple and expeditious; —the teeth are first cut into slabs of the requisite thickness,—then to the proper cross dimensions, by means of circular saws of different shapes. They are afterwards drilled with great accuracy by a machine; riveted to the blade; and finally smoothed and polished. This branch of industry alone gives employment to about five hundred persons in Sheffield. Combs are seldom made of any ivory but Indian. A large amount of ivory is consumed in the backs of hair-brushes; and this branch of the trade has recently undergone considerable improvements. The old method of making tooth-brushes, for example, was to lace the bristles through the ivory, and then to glue, or otherwise fasten, an outside slab to the brush for

the purpose of concealing the holes and wire thread. This mode of manufacture has been improved on by a method of working the hair into the solid ivory; and brushes of this description are now the best in the market. Their chief excellence consists in their preserving their original white colour to the last, which is a great desideratum. Billiard-balls constitute another considerable item of ivory consumption. They cost from 6*s*. to 12*s*. each; and the nicety of our ornamental turning produces balls not only of the most perfect spherical form, but accurately corresponding in size and weight even to a single grain.

The ivory miniature tablets, formerly so much in use, and which are so invaluable to the artist, from the exquisitely delicate texture of the material, are now produced by means of a very beautiful and highly interesting chemical process. Phosphoric acid, of the usual specific gravity, renders ivory soft and nearly plastic. The plates are cut from the circumference of the tusk, somewhat after the manner of paring a cucumber, and then softened by means of the acid. When washed with water, pressed, and dried, the ivory regains its former consistency, and even its microscopic structure is not affected by the process. Plates thirty inches square have been formed in this way, and a great reduction in price has thus been effected.

From the great value of the material, the economical cutting of it up is of the last importance. Nothing is lost. The smallest fragments are of some value, have certain uses, and bear a corresponding price. Ivory dust, which is produced in large quantities, yields a

most valuable gelatine, and as such is extensively employed by straw-hat makers.

The scrapings, shavings, or sawdust of ivory is an article that bears a good price in the market, being much used by pastrycooks and others as a material for jelly, which it readily gives out to boiling water. The jelly thus produced is probably quite as good as that from calf's foot; and the shavings, when dry, have the advantage over calf's foot of not suffering any change by keeping. Another use, of considerable importance, to which bone shavings are applied, is in case-hardening small articles of steel.

In the teeth of the cachalot whale, and of the narwal and other large-toothed animals, we do not find the tubes so dense or curved as in ivory, and consequently they are not of the same value in the arts.

The enamel of teeth is composed of dense prisms

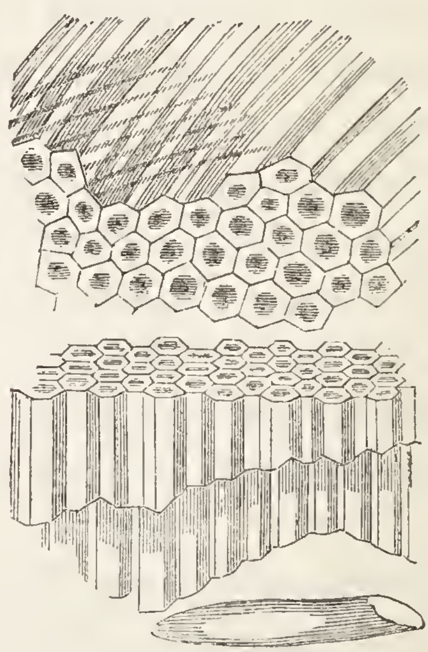


Fig. 13.—*Enamel.*

(Fig. 13), which are so hard that they are cut with difficulty: when thin sections arc made and placed

under the microscope, the whole enamel is seen to be formed of minute six-sided prisms.

The elephants from which we derive our supplies of ivory are the Asiatic and African elephants, the only two species which exist at the present day. The African yields tusks of greater value than the Asiatic. The tusks are the canine teeth of the animal; and it is the male alone in the Asiatic form that possesses tusks; but in the African species both sexes have tusks, and these latter yield the finest ivory. The tusks of the extinct mastodon occur in some places in such large numbers that they are used for ivory; but their dark colour is a drawback on the value of the ivory they yield. The tusks of the hippopotamus and the narwal, and the teeth of the cachalot, have been employed extensively by the dentist; but they have recently undergone an extreme depreciation in value, for the dentist has found a substitute for these teeth in gold and vulcanized india-rubber, which he makes into parts representing the gums and the roof of the mouth; whilst even for the teeth themselves a mineral compound is employed, which renders them harder and more durable than any form of dentine or natural tooth.

Fifty thousand elephants' tusks, weighing 10,000 cwt., are imported every year; consequently, no less a herd than 25,000 of these magnificent animals must die every year to supply the English market alone.

Well, in this, as in so many other instances, you see how curious and interesting are the relations of man to the animal world. Underlying all the wonderful forms which the animal kingdom assumes in obedience to

definite morphologieal laws, we find that the materials out of whieh the bodies and organs of animals are made, possess certain physical and ehemical properties, so altered and so arranged by their vital eonditions, that they become of use to man in his eivilization. It would seem, when we study these wonderful adaptations to the wants of man, as though either every creature was formed first for itself and then for man, or that man was so eonstituted that, in the eourse of his history, he should be able to render every creature by whieh he is surrounded subservient to the purposes of his existenee.

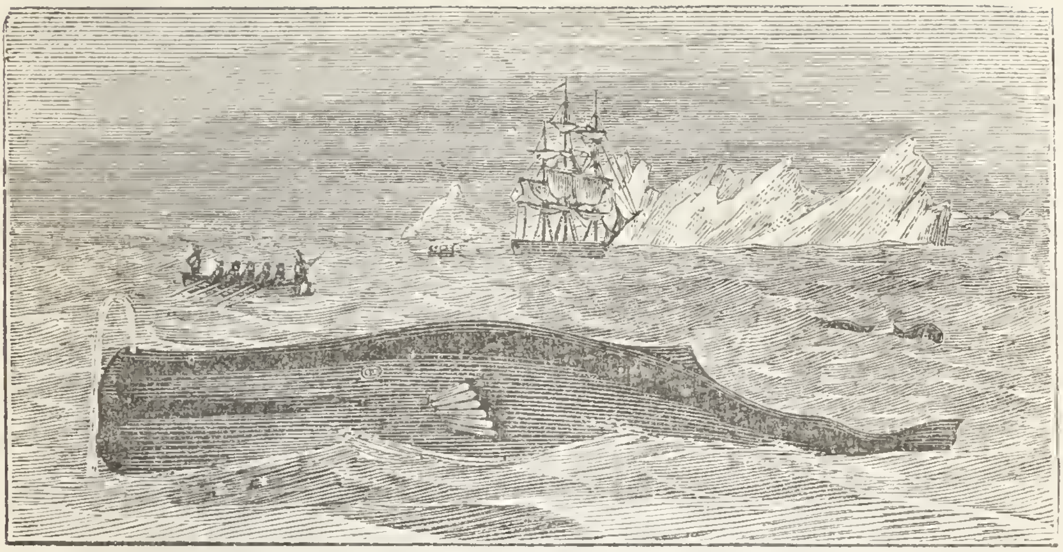


Fig. 1.

ON SOAP.

In this lecture I wish to draw your attention to some other organs or tissues of the animal kingdom. In previous lectures we have spoken of the hairs of the higher forms of animals, of their skin, and their skeleton, and now I would point out the fact, that between the skeleton and the skin there are a number of organs depositing materials which are of great value to man.

The substance to which I shall more especially allude, is that with the absence of which we are so familiarly acquainted when we speak of a man as nothing but skin and bone. When he has much of this material, we speak of him as being well fed, and in good condition, according to the quantity he possesses of this material — fat. It is called adipose tissue, and no animal exists without this substance to a greater

or less extent; and in no case where it exists naturally is it useless. Although we throw away a great quantity of this animal matter as refuse, it could be made useful in the arts. To give you one illustration, I may mention that some three or four years ago a decree went forth in Paris that all dogs that had not owners should be shot and thrown into the Seine, and there they were in thousands and tens of thousands; but the chiffonniers of Paris found out that the dogs had fat, and they collected the dead dogs and boiled them down and separated the fat, which turned out to be very valuable. The quantity of fat thus collected was about one million of kilogrammes. It was more particularly employed in the preparation of kid gloves. It sold at the rate of two and a half francs the kilogramme.

I shall endeavour to impress you with the necessity of a knowledge of the fact, that there is nothing that exists in the form of an animal, that may not be made use of,—that the material elements of which it is composed are of such a nature that they may be applied for a hundred purposes for which man employs the external world. Then let us examine this adipose tissue.

We find it existing in various parts of the animal body; and when we take a portion of fat of any kind of animal, and examine it under a microscope, we find a quantity of cells called fat-cells, which lie amidst the filaments of this tissue, which is called cellular or areolar tissue. (Fig. 2.)

Fig. 2.

Now, these cells are everywhere thrust, as it were,

into the network of the tissue of which the body is composed. The fat of itself does not compose living organs. If you could get at the fat without piercing through the skin, there would be no feeling in it at all. It is deposited in these cells; and there it lies, the cells not getting larger, but increasing in number, the fatty substance being independent of the living tissues of the animal. The tissues around are abundantly supplied with blood-vessels; but the blood-vessels do not pierce these cells. The nerves also run through the tissues, but not through the cells; so that these cells are like the epidermal cells—independent of the structure by which they are surrounded. Now, the matter contained in these cells has a variety of names, according to the circumstances under which it is presented to us. It is called tallow when it is melted down, and it comes into the markets under this name. It is called *lard* when it is prepared for food, more particularly as procured from the pig, and pork lard is a well-known form of fat. It is called *grease* when it is the refuse of fat. Sometimes this grease is mixed with other materials, and then it is called *kitchen stuff*. It is called *suet* when it is hard, and *fat* when it is soft. It is called *butter* when it is soft and separated from milk, and *oil* when it is liquid. There are animal oils and vegetable oils. Before speaking of the chemical composition of this substance, I will explain how this fatty matter gets into the animal tissue.

You will see at once, by looking at a table of our food, that we take in it a very considerable quantity of fat. We take butter with our bread; and then we

prefer meat with fat, or meat that has been fed well; and, taking the leanest part of our meat, it is penetrated with fatty matter. There is fat in fish. Maize contains 7 per cent. of fat. Barley, oats, wheat, and rye, all contain certain portions of fat; so that if we would, we could not avoid taking a certain quantity of fat. The ox and the sheep get their fat directly from the grass upon which they are fed, as oil is found in these things. But there is another source, and that is, the starch and sugar which all herbivorous animals eat. Starch has not the same composition as fat. Fat is composed of—

Carbon	11	parts
Hydrogen . . .	10	„
Oxygen	1	part

But let us look at the composition of starch and sugar; it is—

Carbon	12	parts
Hydrogen . . .	10	„
Oxygen	10	„

Animals are constantly taking these substances in their food. All grasses contain large quantities of starch and sugar. Thus, quite independently of fat, we find the starch and sugar capable of supplying the materials of fat. You see, if we reduce the quantity of oxygen in starch and sugar by nine parts, we have a substance chemically resembling fat; and it would appear that animals, when they take larger quantities than they require of sugar and starch, convert them into fat. Ani-

mals eat more starch and sugar in the summer time than they need to keep up their heat, and the consequence is, that they are converted into fat; but this is lost in the winter. This was at one time denied by the French chemists, and they maintained that animals obtained the fat they had from their food; and we are mainly indebted to them for the knowledge of the fact, that so many plants contain oil, as they sought, in opposition to the Dutch and German chemists, to maintain this theory. Liebig, however, brought forward the celebrated case of the Strasburg goose, which is used for making the famous *pâté de foie gras*. The way they make these pies is to take a goose and put it down upon a board; its wings and legs are then extended and fastened to the board, in a sort of way in which a human being is placed when crucified. But they treat him, as dear old Izaak Walton recommends his reader to use the frog, for bait, "as though they loved him." He is put before a large fire, not to roast, but to keep him warm, and all the time they feed him well. You know the consequences of feeding people well and keeping them warm. They will get fat, especially if they do not take any exercise. Now, that is just what takes place with this goose; and fat being formed from the starch of the barley-meal on which the goose is fed, and not being wanted in any other part of the body, it at last finds its way to a very distensible organ, the liver of the goose, which keeps growing and growing, until at last it nearly kills the animal. It is then taken out and made into the delicious *pâté de foie gras*. Now, said the German, here is the fact proved of starch being converted into fat. But

other proofs are known of the fact, that starch and sugar are really converted into fat.

Now, let me say a word or two with regard to its use in the animal system. Fat is developed much more largely in young people than in old ones. As the fat retires, the angles of the bones begin to be perceived, and what we call ugliness takes place. It is thus an essential element in the beauty of the human form. Then it is a bad conductor of heat. If you take a piece of iron and a piece of fat, and touch them, you will find the iron feels coldest, as it is a good conductor of heat, but the fat feels warm. It is thus supplied to animals in regions where it is very cold, to keep in their heat. We find in the bear and other polar animals large quantities of fat. It serves the same purpose in the great Cetacea. In the whale, the fat is a foot or more in thickness, which prevents the lowering temperature of the water, and it also gives them a lightness by which they are enabled to swim in the water with little effort. There can be no doubt that this fatty tissue is of use to all aquatic animals, by reducing their specific gravity, and thus enabling them to swim with facility in water. Fat is also a store of fuel for animals; and this is a provision for the winter season, when their food is less abundant, and when it contains less of the materials by which they can be heated. That the fat is used in this way, is seen from the fact that animals are always thinner in the winter than in the summer, because they have used the store of fuel put upon their backs.

That fat acts as fuel in the animal system there can be no doubt; for we find that it is the best thing we can

employ for combustion. It contains both carbon and hydrogen, which are the elements we employ for lighting and heating in the gas from coal; and we can get the same gas from oil, though coal is the cheapest. Then, just as these things supply us with the means of artificial combustion, so they supply us with materials for natural combustion. They get into our blood, and we take in oxygen by our lungs, and thus they are burnt in contact with the oxygen in the body; and in this way all animals consume large quantities of fat. Just as a man passes from tropical to cold climates, he consumes fat. In the regions of eternal snow, man eats large quantities of fat, for the purpose of keeping up his heat.

Fat also has another property. It seems necessary to the proper nourishment of the animal body. We find the fat-cells surrounding every tissue; and where there is a deficiency of fat, there we find a deficiency of other tissues. In disease, fat ceases to be developed, and recently fish and other oils have been introduced, for the purpose of being used as medicines, in diseases in which there is a tendency to lose fat. In consumption, this is especially the case, where we find persons getting thinner and thinner every day; but, by administering this oil daily, the fat is deposited again, and with that fat there is a tendency to develop those tissues on which the strength of the body depends. The only well-authenticated cases in which consumption has been suspended for any length of time, is where cod-liver, or some other animal oil, has been administered. This is the reason why the cod-liver oil has been so generally used.

Fat is found in the eggs of birds and in the eggs of insects. In fact, in the very lowest animalcules we find oil. So much, then, for the uses of this substance in the animal system.

I now come to speak of its chemical composition. It assumes a variety of forms,—fat and lard, suets, tallows, greases, butters, and oils; and one would think that the chemistry of these substances was one of the most difficult problems with which we could deal; but, thanks to recent chemistry, we are enabled to explain this subject in a very simple manner. It was in the latter part of the last century that the German chemist Scheele obtained a substance which he called the "sweet principle of oil;" but it is to a French chemist named Chevreul to whom we owe all we know of the chemical properties of this substance, and the true nature of oils and fats. He has recently collected his papers on this subject and published them in a volume, which is, perhaps, unique in the domain of chemistry, on account of the value and importance of the discoveries it announces. The French government thought so much of the discoveries of Chevreul, that they presented him with 12,000 francs. This is a gratifying recognition of the debt society owes to great discoverers, who, whilst contributing to the fortunes of others and the welfare of society, are seldom paid with anything more substantial than words.

I will now proceed to explain the general composition of oils and fats wherever they are found. Eleven proportions of carbon, ten of hydrogen, and one of oxygen, indicate a formula which may be applied to the whole family. Taking these proportions, and putting them

down according to their atomic weight, we shall have—

Carbon	66
Hydrogen	10
Oxygen	8
	84 oil of fat.

In 84 lbs. of fat, whatever may be its source, there will be 66 lbs. of carbon, 10 lbs. of hydrogen, and 8 lbs. of oxygen. These substances are not, as you might suppose at first sight, simply mixtures of carbon, hydrogen, and oxygen; but they are really compound bodies of the same nature as carbonate of ammonia. Carbonate of ammonia is composed of one part of carbonic gas and the other part ammonia; and you know if I take it and put it into a vessel, and then pour on it nitric acid, I shall drive off the carbonic acid gas. The carbonic acid gas comes bubbling off as quickly as possible, and you get nitrate of ammonia. And so, when we take carbonate of soda and add tartaric acid, we get tartrate of soda, and the carbonic acid gas flies off. The composition of oil is of the same kind. It is a compound body like carbonate of soda. The soda is represented by a body called glycerine, or oxide of glyceryle, and the carbonic acid by a fatty acid, stearic or oleic. When soap is made, an alkali is added to the oleate of glycerine, and the alkali combines with the acid and sets free the glycerine. Soap is the salt of a fatty acid. In the same manner glycerine is removed from oils, and the stearic acid which is left, is used for the manufacture of candles.

If you take such an oil as palm oil, or what is better,

olive oil, and set it out in the cold weather, you will find that a white substance falls to the bottom, and that substance the chemists call stearine. The clear transparent fluid part is called oleine. Now, if you take human fat or goose fat—for it does not signify which, and allow it to melt, you will get not oleine or stearine, but another substance, called margarine, which very nearly resembles stearine. I shall not stop here to point out the distinctions between them, except to say that margarine is contained in the human body and is contained in the goose also, but that stearine and oleine are most commonly found in both the animal and vegetable kingdoms.

These bodies, then, are all compounds of an acid and a base. The stearine, as I have said, is composed of stearic acid and glycerine; the margarine of margaric acid and glycerine; and the oleine of oleic acid and glycerine: so that you see glycerine lies at the base of all. I would here call your attention to the fact, that this glycerine is not an inflammable body. But you know what an inflammable body fat is; and, as an illustration, if you take one each of all the candles in the present day that are manufactured from this fatty substance and test them, you will observe that those candles burn best which are made of the fatty acid after the glycerine has been got rid of.

There is another substance which is used for making candles and burning in lamps, which is not an oil at all. This substance is called petroleum. It is at the present day brought largely from the East Indies. It is a mineral production, that is to say, it comes out of the earth, and consists of carbon and hydrogen. From this

is formed a substance which we call paraffine, and this may be obtained in a gaseous, liquid, or solid form. The belmontine of Price's Candle Company is paraffine, and candles are made of it when solid; so that you see this mineral substance has come into competition with oil in the manufacture of candles; and, in speaking of oil, sometimes people speak of this as a mineral oil. But we cannot make soap out of petroleum; therefore it is a very different substance.

Now, I will dwell for a moment or two upon the glyeerine which exists in this fat. When soap is made, an alkali is put into the oil, and the glycerine is expelled, just as when we put nitric acid into carbonate of ammonia we expel the carbonic acid gas; so that when the soapmaker puts his soda or soda lye into fat of any kind with which he makes his soap, he expels this glycerine; and this was formerly the refuse of the soapmaker. It was Chevreul, who has been called the "Father of the fatty acids," who first pointed out its true nature and composition, and that it differed materially from stearic acid and the other fatty acids. Its composition is—

Carbon.......	36
Hydrogen	7
Oxygen	40
	83

besides a quantity of water. And now you see how this glycerine is composed, as contrasted with the other substances in fat. Stearic acid is composed as follows:—

Carbon........	204
Hydrogen	33
Oxygen	24

The oxygen is in much smaller quantity than in glycerine. In the glycerine, the oxygen combines with the hydrogen, preventing the combustion. This, then, is the substance got rid of in soap-making. In order, however, to obtain stearic acid for candle-making, the oil is decomposed by steam. This beautiful process was discovered by Mr. G. F. Wilson, and the oil is thus decomposed for the purpose of obtaining stearic acid for candle-making.

The following extract from a paper read by Mr. Wilson before the Society of Arts gives an account of this process:—

"I will now proceed to describe the new process for obtaining and purifying glycerine, and may remark that the road by which we arrived at pure glycerine was a rather circuitous one. Our first step was to do away with the lime process of saponification, and with it our only source of impure glycerine. By our first improvement in separating the fat acids from neutral fats, the glycerine was decomposed by the direct action of concentrated sulphuric acid at a high temperature; and all that remained of it was a charred precipitate. A new process for decomposing neutral fats by water under great pressure coming under our notice, led us to look again more closely into our old distilling processes; and the doing this showed, what we had often been on the brink of discovering, that glycerine might be distilled.

"In our new process the only chemical agents employed for decomposing the neutral fat, and separating its glycerine, are steam and heat; and the only agents used in purifying the glycerine thus obtained are heat and steam: thus all trouble from earthy salts or lead is escaped.

"Distillation, however, purifies the impure glycerine of the old sources.

"On the table is a series of products of palm oil, which will serve to illustrate the process. Steam, at a temperature of from 550° to 600° Fah., is introduced into a distillatory apparatus, containing a quantity of palm oil. The fatty acids take up their equivalents of water, and the glycerine takes up its equivalent; they then distil

over together. In the receiver the condensed glycerine, from its higher specific gravity, sinks below the fat acids. Sufficient steam must be supplied, and the temperature regulated, otherwise the elements of the glycerine do not take up their equivalent of water, and acroleine is evolved,—a body of a very different character, an acrid eye-inflaming vapour, appreciated only by those who have had the misfortune of an experimental acquaintance with it.

"In an ordinary apparatus, the glycerine distilled from the neutral fat is not in a sufficiently concentrated state for most purposes: it should therefore be concentrated, and, if discoloured, be re-distilled. It is then obtained, in the state of the specimen on the table, at the temperature of 60° Fah.: it is of s. g. 1·240, and contains 94 per cent. of anhydrous glycerine. It can be concentrated to s. g. 1·260, or to contain 98 per cent."

Glycerine, which at one time was the refuse of the soapboiler, is now applied to a variety of different purposes in the arts. It has been used by the photographer for making one of his solutions: it is also used in medicine. It is a good substitute for cod-liver oil: it may be taken in tea. Although not a good substitute for sugar, it still contains large quantities of carbon and hydrogen, and in that way may be taken instead of cod-liver oil. It has also been applied externally; and, although it is the object of the soapmaker to get rid of the glycerine, and you may laugh at him for putting it back, yet the glycerine soap is made by the addition of a quantity of glycerine after it has been manufactured; and, as an external application to the skin, it prevents chapping, and preserves the epidermis, and is very valuable in the winter season, on that account. It is used also to preserve animal matter. Fish have been preserved, I believe, in this glycerine for seven or eight years, and they have perfectly retained their colour and their freshness. It

has been recommended on this account as a preserver of food, which, when kept in it, is free from any taste. The glycerine is soluble in water, and has none of the stickiness of oil, and food may be used with impunity after being kept in it for any length of time. Then it has been used extensively by perfumers; it is used as a cosmetic with carmine, and being rubbed on to the face, gives the colour that youth and health ought to have. There are, no doubt, many other uses to which this beautiful substance may be applied when its properties have come to be more thoroughly understood.

With regard to the sources of oil, the following notes from the Catalogue of the Animal Products at South Kensington Museum will give you some idea :—

"The fat of birds is sought after in many quarters, and esteemed for various purposes, culinary, medicinal, or manufacturing. Goose-grease is considered an emollient or healing application for chapped hands. Peacocks' fat is valued in Travancore and other parts of India.

"An oil of a deep red colour is obtained by pressure from the stomach of the young sooty petrel (*Puffinus brevicaudus*), known in Tasmania as the mutton-bird. It is said to possess virtue as a liniment in rheumatism, and it burns with a clear bright light.

"The guacharo (*Steatomis caripensis*).—This curious nocturnal bird, which is about the size of a common fowl, inhabits immense caves in some parts of South America, and is much sought after for the great quantity of oil which is rendered by the fat of its body. Humboldt gives an interesting description of the slaughter of them in one of the large caverns of the Guacharo mountains, in about 10° 10′; whence it takes its name. Once a year, near midsummer, this cavern is entered by the Indians, armed with long poles, who ransack the nests for the young birds, which are opened as they fall down. The peritoneum is found loaded with fat, and a layer of the same substance reaches from the abdomen to the vent, forming a kind of cushion between the bird's

legs. The fat thus obtained is melted in clay pots over a brushwood fire, and is called butter or oil of the guacharo. It is half-liquid, transparent, inodorous, and so pure that it will keep a year without turning rancid.

"Emu oil is stated to be a very successful restorative in cases of rheumatism. The fat of the emu will, if properly boiled, produce about two gallons of oil. It is supposed that this bird, being deprived of wings, is endowed with a larger quantity of oil to give the muscles freer play, and enable it to move along with necessary facility.

"Fish oils are obtained from a variety of sources: a large quantity is procured in the East from the liver of the white shark.

"Train oil is the general name for the common fish oils, whether obtained from the whale, seal, pilchard, or other fish. It is used by leather-dressers, soap-boilers, for burning and other purposes.

"At one time we prosecuted the whale-fishery with great success; but our merchants seem to have abandoned the enterprise in a great measure to the Americans, who, in the North Pacific, find it one of the most lucrative branches of business now carried on, looking especially at the high and rising price of oil. The Americans have, at the present time, 655 vessels, registering 204,209 tons, employed in the whale-fishery; and the vessels of their Pacific fleet have averaged, for the past five years, more than 1,000 barrels of oil to each ship.

"Under the general name of black-fish oil, several kinds of oil are included. Thus the South-Sea whale is called the black-fish, the pilot-whale (*Globiocephalus Svineval*) is known as the black whale to seamen, and among American sailors the *G. intermedius* is so termed. The common black whale of the Australian seas is *Balæna australis*, and the name is sometimes applied to the *Physeter microps* and the *Physeter Tursio*. The killer or black-fish of the South-Sea whalers is the *Globiocephalus macrorhynchus*. A black-fish of average size will produce from 30 to 35 gallons of oil, which, in its most recent state, has a dark colour and an unpleasant odour.

"The preparation of fish oil is carried on, on the Indian coasts, on a large scale for export to England, and the demand is yearly increasing. Fish-liver oil is prepared at Madras and the west coast of the peninsula.

"In a commercial point of view, the preparation of cod-liver oil is a very important branch of trade, both home and foreign.

"The mode of preparing the cod-liver oil in India is thus de-

scribed :—The proper season for preparing this oil is early in January, when the livers are plump, firm, large, white, and full of oil. The livers are sometimes found diseased, and are specifically lighter than water: these should be rejected. Good livers should cut smooth, and not tear; when cut, none of the substance should flow out in a half-liquid state.

"The quantity of oil produced by livers depends much upon the time of the year.

"In the beginning of January, 1,000 livers were found by experiment to yield 37 imperial gallons, and at the end of February an equal number only gave 23 gallons of oil. In the beginning of January, 1,000 livers of average size weighed 900 lbs., whilst on the last day of March the same number weighed only 575 lbs.

"The oil at these different seasons was equally pale, and the livers equally white, although much smaller and more flabby in the latter season.

"Seal oil is of three qualities—pale, straw, and brown. The oil from the seal is extracted partly by expression, by which the cold-drawn oil is obtained: resort is then had to boiling the blubber in large pans or caldrons. The same method and the same apparatus might be used for extracting the oil from seal-blubber as from cod livers; and when the difference in value of the oil made by the different methods is considered, it is curious it has not been carried into effect. The quantity of oil wasted partly by volatization in boiling in the caldrons, and the inferior value given to the rest by its becoming carbonized or browned, were the whole extracted by steam the advantage would be very great. The quantity of seal and fish oil annually exported from Newfoundland is about 2,750,000 gallons, worth about £320,000, besides some exported from Labrador, and oil to the value of £10,600 yearly consumed in the colony.

"The young seals not taking to the water until they are three months old, are easily killed: their skins, with fat attached, are stripped off, and the worthless carcasses are left on the ice. A majority of the vessels secure from 3,000 to 9,000: they are sorted into four qualities: young harp, young hood, old harp, and bedlamer (year-old hood), and old hood; the most productive being young harp. At St. John's, the head-quarters of the trade, the skins and blubber are separated, and the latter is put into wooden cribs, beneath which are wooden pans to catch the oil. No artificial heat is used in this process. The oil which runs for the first two or three months is pale seal oil, and forms 50 to 70 per cent. of the whole

quantity. As putrefaction takes place, the oil becomes darker and more offensive. The putrescent refuse and the clippings of the pelts yield further quantities of oil (boiled seal oil) by boiling. This old process is being superseded by a steam apparatus. By this invention a uniform and much better quality of oil is produced, free from the horrible odour of that prepared by the old method, and the time required is only twelve hours instead of six months.

"Blubber is the cellular membrane in which the oil or fat of the whale is included. Its thickness varies from 8 to 20 inches, and it yields as much frequently as 100 tons of oil from a full-grown whale. It is generally brought home from the fishing-ground packed in casks. The oil is drained out of the blubber by placing the latter, cut up, on racks, through which the oil drips down into casks. It is then heated up to 225° to deprive it of its rancid smell, and also to make the grosser parts settle. The oil is then pumped over with water, left to cool, and finally stored in casks."

I will now direct your attention more particularly to the nature of soap. I have before explained the theory of its formation. The substance which we call soap is a salt. We take stearate of glycerine or oleate of glycerine; that is to say, stearine or oleine, and add to this a quantity of soda or a quantity of potash. If we add soda, we get hard soap; if we add potash, we get soft soap. This is the process that goes on: the soda goes to the stearic acid, and forms stearate of soda; soap is then a stearate of soda or an oleate of soda. It may be made of margarine, and then it is a margarate of soda or a margarate of potash. You may put in potash instead of soda, and thus form an oleate of potash or stearate of potash, and then you have soft soap, which is also sold as shaving-soap, and Naples soap.

Then we have two sorts of soap formed; the one soluble and the other insoluble. Now, I need not tell you that it would not do to use insoluble soap.

We all know diachylon plaster; this is an insoluble soap. If you look into the Pharmacopœia of the London College of Physicians, you will see that diachylon plaster is made of lead and oil. The lead does just the same as the soda or the potash did; it goes to the oleic acid, and forms oleate of lead; but it is insoluble in water, and therefore we cannot use it for washing. Another insoluble soap is that which is formed with lime. If you take soluble soap and use it with hard water, the soap seems to stick about your hands, and you may think that you can wash a good deal better without the soap than with it. Why?—Because you have got, instead of the soda, lime. We were not using oil in this case, but oleate of soda; and when we add this to the lime, we see what takes place. The lime goes to the oleic acid, and the soda is lost, and the insoluble lime-soap sticks to your hands, just as if you were washing in water containing acetate of lead; and that is what makes hard water expensive, for you keep on washing and rubbing until you get rid of the lime, and then you can go on. I should advise those who are compelled to use hard water to employ soft soap.

The materials used for making our hard soluble soaps are soda and a variety of fatty matters. It would take me much too long to go into anything like detail on the nature of these fatty matters; but I may just say that the coarsest kinds of fat—the kitchen-grease, the grease boiled out of mutton-bones, collected from the kitchens of London, are combined with soda for the purpose of making soap. Curd soap is one of the best kinds of washing-soap, and is made

generally from palm-oil, which makes a better soap than any of the other kinds of oil. At the same time these soaps—the mottled soap, the brown soap, and other kinds—are made of coarser materials than palm-oil; they are made of coarser fats, and to these fats is constantly added a substance which we know by the name of resin. Resin is a product not unlike oils, containing an acid which combines with the soda, and forming a soluble soap, in the same manner that the fat does; so that the resin, as it were, assists in the production of the soap, and is added to the brown soaps, whilst the mottled soaps are made with the coarser kinds of kitchen fat. Now, there are other kinds of soap which have been introduced of late years, and which are supposed to have been manufactured in different ways; but I may say that there is no other way of making soap than by the addition of alkali to the fat, and getting rid of the glycerine; and, therefore, these names are given for the purpose of indicating something that has been introduced. Thus, we find that all kinds of scented soaps are made by the introduction of various volatile oils during the manufacture of the soap. These soaps are put into moulds, and made to assume a variety of shapes. Thus we have fancy soaps, of which there are numberless forms, and which are generally curd soap reboiled and recast. There are also medicated soaps. You may purchase iodine soap and creosote soap, and I do not know whether you could not have any kind of soap you wished; but it is always one of the simple kinds of soap reboiled down and mixed with the special ingredient.

With regard to the soft soaps, they are not so pleasant

to the skin; but potash is a more vigorous detergent than soda; where you want a strong lather, it is very desirable to use strong soap, and gentlemen with strong beards, who do not choose to let them grow in the present day, as the fashion is, find it necessary to use soft soap. Naples soap is a potash soap, and is made in Naples from fish oil.

Now, why do we use soap at all? What is the good of it? After all I have said, I fancy it will puzzle you to tell. We know that we wash with it. But how does it act upon our dirty skins, or linen, or boards, that we should use it in such enormous quantities. Liebig says that the quantity of soap used in a country is a test of civilization; and it is happy for you Britons to know that you use more soap than any other people in the world. At the same time, you know, no one will say we use as much soap as we ought. Well, with regard to its action; in the first place, it dissolves in water, and that is one of its qualities. Again, this solution of stearate of soda has a property of holding in solution oil—of making that soluble which, while on our hands, is insoluble. You rub on a little of this detergent substance, and the oil is dissolved by it, and both are dissolved in the water. The oil on our skin entangles the little particles of carbon, and a thousand things to which we are exposed in the air, especially our faces and hands, and in this way the skin gets soiled, and it is by the removing this oil and its impurities the soap acts as a detergent. But we may add more alkali to the soap, so as to secure the action of the free alkali, and that is what we do in washing. The washerwoman adds soda, so that she makes extra soap. So with the

clothmaker; he adds soda and potash lye to the cloth for the purpose of taking away oil; so that you see the soap acts in two ways; first, by washing away the oil, and next by saponifying the oil. In soaping the skin, we should remember that the alkali will not only dissolve the oil on our skins, but will actually dissolve the little epidermal scales of which we have before spoken, and this will chap the hands and roughen the face; and the consequence is, that by being desirous of cleaning the skin too well, we, on the contrary, roughen the skin, and that renders it more liable to contract dirt. This is the result of using highly alkaline soap. Brown soap, for instance, contains a greater quantity of alkali than curd soap; but the harder the soap the better it is. It requires patience, but in the end it will be seen to serve the purposes of washing better. This is a hint for those who wish to have very nice, clean, white-looking hands.

Now, I must leave soap, and draw your attention for a little while to the manufacture of candles. The use of fat or of fatty matters for the purposes of combustion is very ancient, and we read in all past history that man has employed these fatty compounds of hydrogen and carbon for the purposes of combustion. Wood contains carbon and hydrogen; coal contains carbon and hydrogen. We have no blaze without hydrogen, and we have no solid heat-giving substances without carbon. In all these instances we can easily obtain proofs of the burning of carbon and hydrogen in contact with the atmosphere. Let any one try the experiment. It does not signify whether you take a lamp, a candle, or a gas-light. Cover it with a

glass vessel, and a quantity of vapour will condense in it; presently the light will go out, from the fact that the oxygen is exhausted, and a quantity of carbonic acid gas formed. Now, in this way you get plenty of evidence of the existence of water, as condensed in the inside of the bottle; and if you add a little lime-water, you will prove there is carbonic acid gas, for you will find the water become milky from the presence of carbonate of lime. This is the philosophy of combustion everywhere,—of the great combustion which goes on in our manufactories, our fireplaces, and candles, and lamps, and of the combustion which goes on in our own lungs. In the latter case, we take the fat for breakfast and dinner, and we take in the oxygen by our lungs, and throw off carbonic acid gas.

Formerly tallow candles were used. That was the highest perfection of illumination at the beginning of the present century; they required snuffing, and burnt very feebly compared with more modern candles.—Why? Because in the tallow candle we burn stearic acid and glycerine. It is the latter substance which prevents a more perfect combustion; and, further, if you blow out the lighted tallow candle in the kitchen, the smell becomes very unpleasant, even in the attics—so unpleasant, that if you are asleep it will wake you up. That smell is given out, not by the stearic acid, but by the glycerine. Hence you see, when Chevreul had discovered that glycerine was the base of all these fats and tallows, he put the candlemaker in the way of getting rid of the substance which was most objectionable in the tallow candles—at the same time he never succeeded as a candlemaker; I believe he tried in

Paris some twenty years ago, but failed altogether. It was left for practical Frenchmen, and still more practical Englishmen, to realize the benefits of all his discoveries. The improved candles used in the present day, are all the result of this discovery. The tallow candles are made by taking a quantity of cotton and dipping it into the hot tallow, and redipping it again and again till the candle is made; hence they are called "dips:" but the mould candle differs in being made in moulds or tubes, which are filled with the tallow, instead of being dipped; they burn better than dips. The aggregate weight of tallow candles, dips and moulds, turned out in the United Kingdom, is known to be about 1,000 tons weekly, or 52,000 tons per annum; and the general wholesale price being now about £60 per ton, shows the value of the manufacture to be £3,120,000.

Stearic acid candles are the candles which contain the fatty acid alone, and they burn best; however, when you deprive the candles of glycerine, you have made a candle that is very expensive, and this becomes a matter of serious importance. It was, however, left to Mr. J. P. Wilson to invent a candle, now called a composite candle, which consists partly of cocoa-nut stearine and partly of stearic acid, and which does not require snuffing, and gives out but little scent when blown out. It is these cheap, good candles which are sold in such large quantities in this country, not manufactured by Price's Company alone, but by every maker throughout the country.

There is another series of products made by Price's Candle Company, consisting of candles known by the

name of night-lights, which are interesting things, as constituting a manufactory in which a very large number of children are employed. The process of manufacture is very simple: pieces of wood are planed and split into thin layers, and rolled up into the form of a box; this is then handed on to a boy, who inserts a piece of wick, and then it is handed on to another who puts in the fat; and in the course of a very few minutes, the night-light is made. There are hundreds of little hands employed in this way, and in the course of a day several thousands of these night-lights are made, which are exceedingly useful when only a small quantity of light is required. You may have night-lights made to burn any number of hours, and of any size. I saw a number of night-lights which had been made for gardening purposes, and they were used for placing under a glass case in which plants were, and which required a higher temperature than our atmosphere. By the aid of these little lights, people might hatch their own chickens, by placing the eggs in sand, and raising the temperature to the point at which the chickens are hatched.

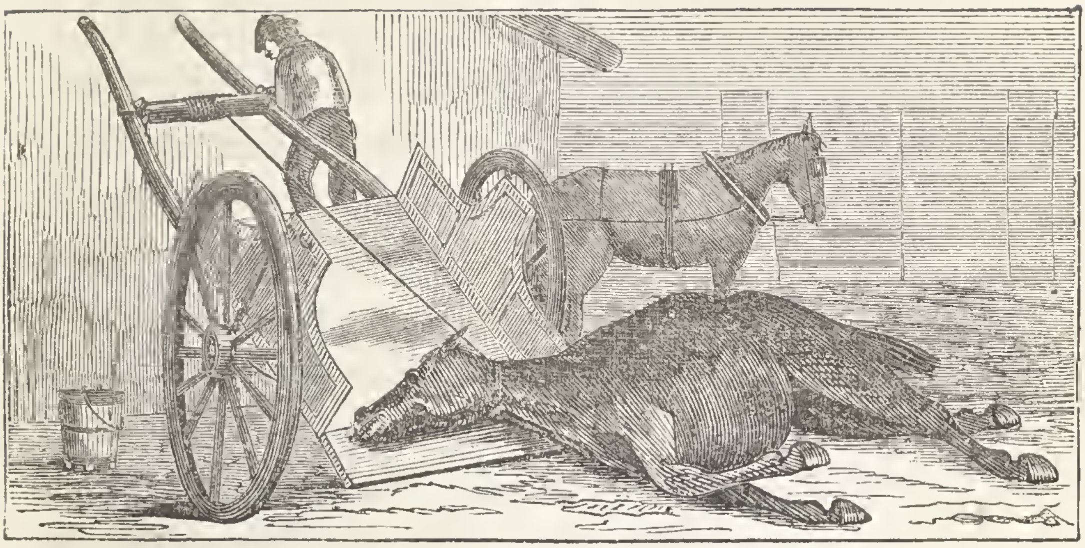
There is one substance that comes in competition with fats and oils for making candles, and that is spermaceti. Spermaceti is not fat, but it is very like it. Instead of glycerine, we have an oxide of cetyle; and it is not now worth explaining the difference in the nature of these substances. Now, where does spermaceti come from? Why, from the head of the great whale—the *Physeter macrocephalus*. This whale, which is remarkable for the large size of its head (Fig. 1), is found in almost all seas, but is now most frequent in

the Southern Ocean, on the coasts of America, Japan, Lima, and New Guinea. It is one of the largest of living animals, and attains a length of eighty or ninety feet. Of this length the head occupies a third. In the head is a cavity called a case, in which is deposited the spermaceti. The head of a single whale has been known to contain as much as a ton, or ten barrels, of the oil and spermaceti. This oily matter is lighter than water, and thus the animal is enabled to float easily in the water, in spite of its great bulk, and to lift out its great head for the purpose of breathing. This process is called the spouting of the whale, as during expiration it throws out the air, mingled with particles of water, so that the stream of air can be seen like a spout. These whales are generally gregarious, and hundreds of them are often seen together, forming what is called a "school." The larger males, however, feed alone, and are then easily approached and caught. When the animal is captured, the spermaceti is taken and compressed, and separated from the sperm oil, and afterwards bleached; and then you get the beautiful white substance called spermaceti. It is easily melted and poured into moulds, and then it makes candles, which burn as well as tallow candles. They are more elegant, give as much light, and do not smell, and they are really worth the money they cost as compared with tallow. Many thousands of tons of spermaceti are brought into this country in the course of a single year, and manufactured into candles. The candle-manufacturers thought, when gas was introduced, that they must get ruined; and then the spermcandle-maker, when the

improved oil candles were introduced, thought he should get ruined. But the people of this country still burn sperm candles in preference to others Thus it is with men engaged in business. The papermakers and the winesellers, now that the duties are going to be reduced, fear they are going to be ruined; but so far from what they anticipate being realized, new discoveries and lower prices always lead to increased demand, increased energy, increased business, and in the end increased competition and benefit to society.

Now, spermaceti has some other uses besides that of burning. It is mixed with yolk of egg, and made into a very pleasant mixture for colds and coughs. Sperm oil is extensively used in our large manufacturing towns. It is employed for the purpose of diminishing the friction of those wheels which are daily producing so many of the necessary comforts of our life. Not only sperm oil but palm oil, and all oils, are used for diminishing this friction, by which we are enabled to work the wheels of our machinery, to spin and to weave, to travel quickly on railroads, and to pass rapidly over the broad ocean. The diminution of friction by oil is one of the great elements of our civilization; that is another reason why we are so anxious to get these oils from all parts of the world. The fats of this country are insufficient for its exigencies, and, therefore, the fat of the horses of the Pampas of America, and of the bears of the Arctic regions, and the oxen and sheep of Africa, and the oils of the palm-trees of Africa and Asia, are brought into this country in immense quantities.

In the application and uses of fats and oils we have a wonderful instance of how a knowledge of the nature of a substance increases man's power of using it and applying it to the purposes of his life. The same results await his discoveries in every direction. It is by these discoveries that he is raised in the scale of civilization, and becomes more and more the master of the world in which he lives. Yet it is precisely these very studies that he systematically neglects. Up to this moment, in this country, neither the Government nor the people have made any systematic attempt to teach the principles of the sciences on which our whole national industry depends; nay, every attempt to do so is treated with more or less of ridicule and contempt, and we are told that the multiplication of words for a fact, and a knowledge of figures that represent nought but mental abstractions, are the only training necessary to fit man to enter on the career of life. Surely the accumulating evidence that man advances only as he knows and applies the laws by which God governs the world in which he lives, will at last open the eyes of the people of this great nation to the necessity of teaching every one who is born into this world all that he can know of the uses and reasons of his existence.



ON WASTE.

"*Gather up the fragments—let nothing be lost*," is a divine injunction for us in every age. We recognize it most strictly, I hope, with regard to our food, but, perhaps, we are not so particular with regard to the fragments that are likely to be lost in our manufacturing operations. If we look abroad upon the world, and see how God is governing the universe—sec how he is correlating the powers of nature and the properties of matter, we shall see, there, indced, that nothing is lost; we shall find that no force ever assumed by an atom of matter is wasted. Matter is perpetually changing its forms, but whilst changing its forms it is ever subserving some use in nature. Man should study these laws, and examine the works of the

hand and the finger of the great Creator in the external world, and try to imitate him. It is man's privilege to be created in the image of his Creator; it is his privilege to follow in the footsteps of his Creator. He is placed here the monarch of the world, and it is only as he fails to understand his duties in attaining a knowledge of the laws of the external world, that he suffers pains and penalties. I want to show you that if we imitate in our manufacturing processes the great laws of nature, we shall save much, and we shall also diminish our labour and multiply our sources of happiness on the earth. We can see it in some things more obviously than in others. We can see it in the mineral world. When the workman is at work on the diamond, he suffers not a grain of its dust to be lost or wasted, but hoards it up for future use. So with the workmen in gold and silver. We find that the particles of dust that escape in various directions are carefully collected;—and it is not less true with regard to vegetable products. We see the shavings and sawdust of the carpenter and cabinet-maker carefully collected together for other purposes and uses in the arts and manufacturing operations; and it ought to be no less so in the animal kingdom, in the use of the animal products. With this view, I propose to-night to see whether there have not been some fragments thrown away in the manufacturing operations we have spoken of, that we may point out how that which is now lost may be saved.

There is an anecdote told of a distinguished chemist, who was asked how he had made his great discoveries, and he replied that it was by examining that which

other chemists threw away. So many a manufacturer may make his fortune by using that which others throw away.

In the first instance I will call your attention to the chemical, physical, and general propertics of the materials of which we have been speaking. We spoke of these to some extent in the first Lecture; we saw thatthe animal tissues possessed certain properties which made them valuable in the arts, and we found that these substanccs were formed of certain chemical elements which exhibited definite chemical properties; and we shall see that a result of this study is a knowledge of the application to the arts of life of these substances which would otherwise be lost and thrown away.

I purpose first to examine some of the substances which, on account of their physical properties, are now recovered, and which at one time were regarded as waste. I spoke to you first of silk, and I referred to the way in which the silk is wound off the cocoons, and how it is rolled and afterwards spun, and formed into a variety of garments.

During the operation of spinning there is a quantity of loose silk, which would be entirely lost but that pains are taken to collect it in a rough state; it is then pulled out, and the fibres again reeled, and it is manufactured into the lower kinds of silk. The wastc of this process is collected again, and again it is re-reelcd and wound; so that not a fibre is lost. After the silk of the cocoons has been wound off, there still remains a quantity of silk upon the used cocoon, which, under the name of "knubs and husks," is imported into this

country. The knubs and husks are torn to pieces, and the fibre is reeled and woven into the lower sorts of silks; so that there ought to be no waste in silk at all. I told you, I think, that the Chinese even eat the grub within the cocoon.

I pass on from silk to wool. During the process of spinning and weaving wool, there is a quantity of waste —a quantity of the hair is left; but this is now collected, and applied in a variety of ways. Some of the better kinds of this waste wool can be used and mixed with higher sorts, and are thus worked up. We find that, after the cloth is woven, the ends are cut off, under the name of *list*, which is again torn to pieces and re-wound. There is also from such waste portions an extensive manufacture carried on of the substance known by the name of flock. The wool is ground down to a powder, and mixed with colouring matters, such as vermilion for red, chromate of lead for yellow, arsenite of copper for green; so that the flocks assume a variety of colours; and these coloured flocks are used for the purpose of manufacturing what are called flock-papers. The paper is figured in a variety of ways, and the figures are covered over with size or gum, and the flock is powdered over it: it is then called flock-paper. This process was first patented by a Frenchman named Jerome Lanyer, in 1634, and since his time there has been a considerable manufacture of flock-papers in this country. It has, however, reached great perfection on the continent, and the French have paid particular attention to the patterns. These flocks, then, have been produced by the refuse of the woollen manufacture.

I would here say one word with regard to the

colouring matters of flock-papers, as it is a matter of importance. They should not be mixed with poisonous substances. The greens are mostly made with arsenite of copper; and instances have not been rare of persons living in rooms where these green flock-papers have been used; and the consequence has been, that when the paper has been brushed, the particles of arsenite of copper have got into the air, have been taken into the lungs, and produced injurious effects on the system. I do not know that it is so deadly a thing as represented, but it seems an imprudent thing for people to live in rooms covered with these green papers. Wherever these flock-papers are used, they accumulate a greater quantity of dust than other papers, and consequently require to be brushed oftener. It is undoubtedly much the most wise and prudent plan in the case of paint, and in the case of all substances employed in rooms where persons live, that they should not contain poison.

This arsenite of copper has been the source of a variety of suffering in many directions. It is sometimes used to colour confectionery, and I have known children killed by it. The green fields and green trees looking so pretty, with the white sheep feeding on the top of twelfth-cakes, have been known to contain arsenite of copper. I recollect a case of a number of people being poisoned at a dinner-party by eating some nice green *blanc mange,* which had been coloured with arsenite of copper. With yellow orpiment, a sulphide of arsenic, some boys were recently poisoned by eating Bath buns made yellow by this substance.

Now let me draw your attention to the fact that the wool, after it has been used—after it has been worn, has

its analogue in the rags of linen and cotton clothing. You know how desperate has been the condition of the paper manufacturer because he cannot get a supply of rags for his manufacture. The woollen manufacturer has been saved from the same state by a material which is produced under the name of "shoddy," and which is extensively used in the manufacture of clothing of common quality, such as pilot-coats, ladies' mantles, druggets, and the cheaper kinds of carpeting. This material is not made of new wool, but of wool that has been worn and afterwards torn to pieces by machinery. This shoddy has various prices in the market, according to the substances from which it comes, and you will find the specimens of the material under various names, such as "black and grey army clippings." I suppose they are the torn-up clothes of soldiers, who, probably, have been in the field of battle, and having come back, have sold their clothes second-hand. Then we have "seamed middle white." I do not know what kind of cloth that has been. Then "scarlet cloth." Then there is "Hamburg blue-stocking shoddy," and shoddy from "black stuffs," from "brown stuffs," from "white serge," from "druggets," and "carpets." I mention these names to show you what a variety of substances are thus torn up, and made again into new cloth. Some forms of this shoddy are called "mungo." Thus we have "blue mungo," "brown mungo," "grey mungo," "claret and white mungos;" and there are now shoddy markets, just as there are woollen markets, and the shoddy markets are increasing every day. One principal seat of this manufacture is Dewsbury, in Yorkshire. It has, however, found its way into Leeds,

Wakefield, and to all the large woollen-manufacturing towns. Those who are skilled in the knowledge of real woollen cloth can easily distinguish between it and shoddy. This trade has been sometimes objected to on account of its appearing to produce an article of a superior kind with an inferior raw material; but, after all, you will find that these shoddies are not sold at the price of superfine cloths, and are good substitutes for them. The cheap clothing of late years has depended upon the introduction of this shoddy, and, provided the price is not larger than gives the fair profit to the manufacturer, we cannot object to it, as it enables many a man to put on, at least once a week, a decent-looking coat, who otherwise would not have a cloth coat at all; and if the wear only answers to the price given, I do not think any one can find fault. However, I have heard a gentleman say he objected to stockings of shoddy, which he could not put on without putting his feet through them, and to coats that split up the first time they were put on. In this case the purchaser must judge for himself, for there is no attempt to sell them as superfine cloth,—they are sold as shoddy I introduce this subject to you to show you that it is one of the uses of waste substances. I shall show you that even after wool has been manufactured into shoddy, it has still further uses in the arts. It has recently been observed that "there is still some mill waste which cannot be used up again for 'shoddy.' It is that portion of the wool waste which is so saturated with oil and grease that the fatty matter is heavier than the wool in it: it is called 'creash.' This is one of the most powerful fertilizers. Those farmers who laid it upon

land several years ago are seeing the advantages of it every succeeding year; for it does not give out its strength to the crops all at once, though by a chemical process it could be made to yield its nourishment as speedily and be as good as guano to the enterprising agriculturist. The attention of the agricultural chemist may also be directed to the quantity of liquid manure in the soap-suds and washings, &c., which run to waste from the mills. This liquid contains the best fertilizing elements which can be found; indeed, farmers are in the habit of paying £7 a ton for substances which can do less good to their crops than despised 'soap-suds' would do."

Passing on from shoddy to leather clippings, I will mention that a patent has been recently obtained for cutting up the clippings of leather, and introducing them into the soles of boots and shoes, rendering them easier to the wearer and quite as durable; thus saving new material. Leather cuttings are also employed in the manufacture of Prussian blue. I have recently had some paper presented me by the Messrs. Schlagentweits, the celebrated German travellers, made in Berlin, from the cuttings of leather. The paper is remarkably tough, and apparently adapted for serviceable purposes; but it has not yet been used in sufficient quantity to render it a profitable manufacture.

I have hitherto been speaking of the physical properties of waste substances; but waste matters are composed of chemical elements, which can be changed into other compounds by which we can get new substances; and some of our most extensive manufactures depend on this fact. All the substances of which I

have spoken—the clippings of leather and the fibres of wool and silk,—whatever animal substances we may have, are composed of the four elements,—carbon, hydrogen, oxygen, and nitrogen. We find all these elements in carbonate of ammonia. Now the difference of these elements, as they exist in the carbonate of ammonia and as they exist in bones, or in hoofs, or in horns, or in wool, or in skin, is this—that the elements of the animal body are much more easily changed, and more readily made to assume combinations which are useful to man, than if he had to deal with mineral compounds. Hence it is that he prefers to work chemically at the gelatine or wool, or some other constituent, than to take carbonate of ammonia, which is cheap enough but not the easiest to work with.

With this view I will now speak of skin waste. The tanner has waste. While he is preparing his skins, he cuts off the fat and the portions which cover the legs and the ears. He sells all these. The oil and the fat are sold to those who boil down oils and fats of all kinds. You will recollect that the oils and fats can be made into soap; and it is no matter whether the oil or fat be obtained from skins or from other sources. Then again this oil and this fat, obtained from the tanners' waste, is made to yield its stearic acid. Its glycerine may be obtained for all the purposes to which it can be applied, and its stearic acid may be manufactured into candles. The bits of skin are carefully collected and boiled down with various other odds and ends of animal substances. The various sources from which these pieces and scraps of skin are obtained are very numerous. They are bought by the manufacturer, and

after some process of selection, they are placed in large vessels and boiled in water, and thus they are made to yield gelatine. The oil contained in those substances floats to the top. If the manufacturer wants a coarse and common tallow, it is employed as it is taken off; but if you are to have a better kind, it is afterwards prepared with great care. The water being evaporated, the gelatine is then procured. If the gelatine is to be used as size in the arts, it is less carefully prepared than if it is to be sent to your table as isinglass; and, let me tell you, whether you get the isinglass from the sounds of the sturgeon or from these things, it is all the same to you; for they are boiled down and purified, and can do no harm. Perhaps, with regard to these materials which have the same composition, from whatever source they are derived, it is best to ask as few questions as possible. The manufacturer of gelatine asks no questions, and perhaps it is prudent that you should ask none. This gelatine is certainly a very interesting substance, on account of the great variety of forms it assumes. According as it is used for one purpose or another, it is prepared carefully or not. When it is used in the arts for adhesive purposes, as in the form of glue, it need not be so destitute of colour or so carefully prepared. On the continent it is now manufactured into all kinds of forms. Large sheets are made for the purpose of colouring glass, for cutting up and forming into artificial flowers. It is used for the internal decoration of rooms, and for the wrappings of sweetmeats. Those who are in the habit of cracking *bonbons* at the supper-table will recollect that they are wrapped up in this coloured gelatine. This manufac-

ture is entirely dependent upon the use of what was a few years ago regarded as waste material.

I now come to the waste in bones. I mentioned that buttons were made of bones, and handles of knives, and a variety of useful articles, are made of bones. The buttons are punched out of the bones, and the pieces that are left are not lost. The dust made in sawing bones is collected; and butcher's bones and household bones are all used. They are first boiled down, and the fat is taken off, as in the case of the skin, and then their gelatine is dissolved, and the gelatine is used for glue, or size, or isinglass. In the bone that is left, there is still useful material, which may be employed for various purposes. The refuse of the bone-boiler is now commonly introduced into a closed furnace, by which a peculiar kind of animal charcoal is produced. So you see that after they have made buttons they are used for making size, gelatine, jelly, soap, and candles, and then they are still available for making animal charcoal. This charcoal, for many things, is better than any other; and this raises the question why this is the best? There is another form of animal charcoal obtained from burning blood, and which may be considered the best animal charcoal, because it contains the largest quantity of carbon; but it is found that this bone charcoal is better for filtering purposes than the ordinary animal charcoal, and at this moment it is fetching a higher price in the market. It is used especially for filtering water and refining sugar. You know that sugar is brought into this country in a brown state. Here it is melted and purified by passing through animal charcoal. One filtration is not sufficient, but a second is; and the

charcoal which is found to be most efficient is this charcoal which is made from the refuse of bones after all the gelatine and fat have been extracted. It is probably, then, not so much the carbon which strains and keeps out this organic matter, as the phosphate of lime. Now, I do not mean to say that any one would make a fortune by it, but it is worth consideration whether common vegetable charcoal mixed with phosphate of lime may not answer as well. Here, perhaps, we may inquire how it is that these charcoals act as purifying agents. I may say that this purifying action is not confined to water and sugar, but that chemists use animal charcoal as a means of purification for a variety of processes. It would seem, with regard to the water, that the animal charcoal has a power of absorbing and holding, and, as it were, introducing oxygen to the impure substances contained in the water, so that they become oxidized and converted into something else; for we find that the animal charcoal retains its power of purification for several years. If, instead of oxidizing these substances and passing them through, it acted as a strainer or sieve, straining out the impure materials, then you would have the charcoal blocked up; but it is not so. These impure substances in water are all composed of carbon, hydrogen, and nitrogen. The oxygen oxidizes the carbon, and forms carbonic acid gas, which makes the water sparkling and refreshing. It oxidizes hydrogen, and converts it into water: it oxidizes nitrogen, and converts it into nitric acid. One of the impure-smelling substances in water is sulphur, and the oxygen unites with it; and thus we get sulphuric acid, or sulphates. Thus the impurities

of the water are converted into substances which may be consumed without any injury whatever.

This, I think you will say, is a most remarkable instance of the application of waste to important purposes. This has really arisen out of the necessities of the bone-boilers, who, when they had obtained the fat and gelatine out of the bones, left them to accumulate and engender and send forth a smell of sulphur and ammonia, and other compounds, which made people object to the annoyance of bone-boiling houses near to them; and now, instead of allowing these bones to lie and produce these ammoniacal compounds, they are at once thrust into a furnace, and converted into charcoal. Now, these things encourage us to go on. Let us not be beaten by bad smells. All these substances which throw out disagreeable odours—all these may be conquered and made to serve our highest and best purposes in life. The very sewers' smells, which are so injurious in the summer season of the year in this metropolis, even these may be made to form compounds with other substances, which, being conveyed on to the land, actually fertilize it; and the compounds of carbon, oxygen, hydrogen, and nitrogen of the sewers become the compounds which feed us in "our daily bread."

Then, suppose you had used your animal charcoal, and that it had become blocked up, what are you now to do with it? You cannot reburn it: but although it will not bear that process, it still contains phosphate of lime; it still contains that precious constituent which forms part of our bones, and the bones of the lower creatures. We must have that in our system, and where are we to get it from? The bread which we eat

from day to day must have it. And where is the bread to get it from? Why, from the land on which it grows. If the land will not grow wheat, and the meadows grass, they must be made to do so. The soil may become exhausted, and has again and again been exhausted. We have instances of farms which have ceased to grow wheat because they have no more phosphate of lime. There are meadows which fail to grow grass because of the want of this phosphate. Then how can the farmer remedy this? In no way but by applying the phosphate to the soil; and this he may do by applying to his land the refuse of our great cities. But we may throw away our phosphate, we may pour it into our sewers and rivers, and thus destroy it, whilst our crops are exhausting our fields;—and this is the history of the great empires of antiquity. Why have they ceased to exist? History will give you a variety of reasons why they have sunk. Some will tell you that it was because of their immorality, and others because of their civilization. But you will find around the great cities of antiquity, of Africa, of Asia, and of Europe, that the soils have become exhausted of their phosphate of lime, and consequently their crops have failed. Man could not then bring his food from great distances, and he has been compelled to seek his food on unexhausted soils. On this account the great cities of antiquity have been depopulated, and new colonies have sprung up in every part of the world. But modern chemistry has shown man how he can avoid this necessity. It has pointed out that we have in these decaying bones the material of future life: it has shown us that in the earth are the bones of extinct animals containing this

precious phosphate of lime. Thus we now bring up these creatures of a pristine world, and throw their ashes on our land to fertilize our fields. In the form of coprolites and phosphatite, we now get this phosphate of lime from the green sand of Cambridge, the red crag of Suffolk, the lias of Gloucestershire, the weald of Sussex and the Isle of Wight. This phosphate, in a mineral form, has also been found in Estremadura, in Spain, that country of never-ending wealth. There it exists in thousands, tens of thousands, probably millions of tons; although Spain has not yet arrived at a knowledge of the importance of this substance, and sends little or none into the markets of Europe. We get it, however, from Sweden and Norway, and other parts of the world. And here we have an instance of the use of that which previously had no value, being made subservient to the highest purposes in the life of man.

The dust of bones and ivory is sold in the shops, and used for various purposes. Ivory filings are collected most carefully by the ivory-turner, and sold as ivory-dust. Jellies are made from ivory-dust, and they are supposed to be more nutritious than jellies made from other things. I have, however, told you, in previous lectures, that gelatine is not nutritious. However, we have in this ivory-dust phosphate of lime, and it may be that a portion of the phosphate is thus introduced into the system. Then, bone-shavings are used as a substitute for ivory-dust, and are employed for the purpose of making a jelly which is frequently administered to the sick. Ivory-dust and bone-shavings are also employed for making a size.

Passing the refuse of leather, skin, bone, and ivory

manufactures, I come to a curious instance of the application of refuse to purposes in the arts. If you recollect what I said more particularly with regard to the preparation of cloth, you will remember that I stated that soap was frequently employed for the purpose of washing away the oil and other impurities in the wool. Now, this soap is used in such large quantities, that soap-suds have become a source of annoyance in the rivers in cloth-manufacturing towns; and it has occurred to chemists, that if the materials of the soap could be collected, they are of considerable value; and in some places there are arrangements made for arresting the suds, which contain both potash and oil in large quantities. When collected, sulphuric acid is added to the suds, and the soap is thus decomposed; the potash and the soda go to the sulphuric acid, whilst the fatty matter floats on the top; and in this way large quantities of useful matter are rescued from destruction in our manufactories. The fatty matter which rises to the top of these soap-suds is skimmed off and made into soap again, or into candles, or converted into other products in which fat is used. I do not know whether, in our domestic arrangements, it would be economical to keep a bottle of oil of vitriol, to enable us to skim off the fat from our soap-suds, but, at any rate, it is an interesting application of refuse, and ought not to be lost sight of.

Now, let me call your attention to another process. The fragments of woollen clothing, bone drillings, whalebone shavings, hoofs and horns, button-makers' refuse, horn-shavings, dried blood, woollen waste, all sorts of animal products, the sweepings of manufactories, the

lost atoms, which could not be used or employed for anything else in the respective manufactories, are used for making crystalline salts, known by the name of *prussiates*. There are two of these prussiates generally known; one is a beautiful yellow salt,—the other is an equally beautiful red salt.

And what are these prussiates? It is just worth while studying them for a moment, to see what curious compounds result from animal chemistry. The word prussiate comes from prussic acid (which comes from Prussian blue), which is also called hydrocyanic acid, and which is composed of hydrogen and cyanogen, and the latter is a compound of carbon and nitrogen. Old scraps of iron are collected together, and with potash and animal matter form these prussiates.

In order, then, to obtain these salts, we take three sets of substances:—1. Refuse of animal substances—blood, bones, hoofs, horns, &c., which yield nitrogen and carbon. 2. Old scraps of iron,—refuse iron, shoes from dead horses, rusty nails, and worn-out iron hoofs. 3. Potashes, Montreal ashes, the refuse, if you like, of hewn trees; and these supply the potassium. Now, when these things are exposed to heat together, they arrange themselves in this way:—the iron unites with the carbon and nitrogen in the form of cyanogen, forming ferro-cyanogen, and this compound unites with the potassium, forming the ferro-cyanide of potassium; and this is what these salts are—ferro-cyanides.

I will not go further into the history of these prussiates, but just say a few words about their use. I do not know that there is any use for this prussiate of

potash alone; but let us see how it acts in combination with iron. There are two proportions of cyanogen, and two proportions of potassium, and one of iron. Now, if we take a solution of iron and add it to a solution of this yellow salt—this prussiate of potash—it will be converted into a beautiful blue substance. This is Prussian blue—Berlin blue; and it is the base of all the blues that are known by that name, and the base of many other colours also. What is this Prussian blue? Why, it is a ferro-cyanide of iron. We displace the potassium by the addition of the iron, and thus form this important dyeing material. This is obtained, then, from waste made up of the sweepings of our manufactories, the refuse of our slaughter-houses, and blood and filth of all kinds. Man comes in, you see, as creator, builds up the elements, and makes all these beautiful colours with which he dyes his silk, and makes blues for his calicoes and other materials. The Prussian blue is also mixed with flocks, and is used as a pigment, being extensively employed wherever a blue colour is an object.

Now, there are many other things which I might speak of in connection with this large subject. I might show you that some materials which look unlikely to be employed in the arts for any useful purposes, have been employed in that way. Recently there has been an attempt to use the substance which we know by the name of guano. We bring it over to this country on account of the phosphates which it contains. A series of beautiful colours have been obtained from this guano. If we take a little of it and mix it with nitric acid, we shall find that it will produce the beautiful

colour of murexide. In the South Kensington Museum there is a series of colours which have been manufactured from guano. A few years ago, the test of the action of nitric acid upon the substances contained in guano was merely an amusement or chemical test: nobody ever thought of using it in the arts. But now, these substances are manufactured in large quantities, and guano is used successfully in the arts.

These beautiful colours do not, however, depend on the phosphates of the guano, but upon the lithate of ammonia. When we add nitric acid to this substance, the purpurate of ammonia, or murexide, is produced. According to the way in which the guano is heated, will be the variety of results obtained. This is just one of a hundred applications of chemical knowledge to substances having a similar nature to guano.

I was asked the other day whether I had ever seen the colouring matter produced from an insect (*Cimex lectularius*) uncommonly disliked in this country. Some one in Australia, it was stated, had taken out a patent for procuring a beautiful colouring substance from this little creature. And if this should be the case, there is no doubt that they would run the hazard of extermination. I do not know whether this process has succeeded, but it illustrates the fact that there are hundreds of common things around us which may be made useful by the application of industry and intelligence.

Speaking of insects and their products, I must here remind you that to the insect tribe we are indebted for chloroform—one of the most powerful agents in alleviating human pain. The little ant contains a

substance called formic acid, about which old John Ray and Martin Lister corresponded a century ago; and they found that it contained an acid; and so it got into books as formic acid. It was found to be composed of a compound radical, formyle, and three atoms of oxygen. Dumas substituted chlorine for the oxygen, and thus obtained terchloride of formyle, which is chloroform. Then the Americans found that ether was capable of taking away all sensation from the human body; and Dr. Simpson, of Edinburgh, found that terchloride of formyle was more thoroughly adapted for this purpose than even ether. All this has arisen from a study of the habits of insects. There is no telling but that every insect has some use in relation to man. Such facts are inducements to study. Be not dismayed by obtaining no immediate results. Surely it is some reward, even if we do not get a money payment, to feel that we have not lived in vain; that we have exerted our brains to the utmost to fulfil the mission that God sent us to perform on this earth; and that we have left the world wiser and better for our work in it. But you may be assured some people will get the money. You and I are the better for rich men· These large capitalists are not keeping the money in their pockets: they are spending it in a variety of ways. It is the wildest of theories to think rich men are an injury to the poor: they better the poor man. Then let us help the men to get rich, seeing that they cannot deprive us of the blessings of intellectual research and exertion.

But here I must cease my illustrations from the insect kingdom. The subject is a large one, and I

hope some day again to bring it before you. I have before said there is no part of an animal which is not of use. So when they are dead, they ought not to be buried or cast away. I wish here to illustrate the whole subject of the uses of dead animals by this diagram, drawn up by Dr. Playfair, which gives you the value and uses of a dead horse. The value is not a large

Value of a Dead Horse from 20*s.* *to* 60*s.*; *Average Value,* 40*s.*
Weight in Pounds, from 672 *to* 1,138; *Average Weight in Pounds,* 950.

—	Weight.	Value.	Uses.
	lbs.		
Hair . . .	1½	8*d.* to 1*s.* per lb.	Hair-cloth, mattresses, plumes, and bags for crushing seed in oil-mills.
Hide . . .	30	About 8*s.*	Leather.
Tendons . .	6	—	Glue and gelatine.
Flesh . . .	Boiled 224	1*l.* 8*s.*	Meat for men, dogs, and poultry.
Blood . . .	60	—	Prussiate of potash and manures.
Heart and Tongue	—	—	A mystery.
Intestines . .	80	—	Covering sausages and the like.
Fat . . .	20	3*s.* 4*d.*	Used for lamps after distillation.
Bones . . .	160	4*s.* 6*d.* per cwt.	Knife handles, phosphorus, super-phosphate of lime, bone dust.
Hoofs . . .	6	8*s.* to 10*s.* per cwt.	Buttons, gelatine, prussiates, and snuff-boxes.
Shoes . . .	5	5*s.* to 10*s.* per cwt.	Shots and old iron.

sum,—from 20*s.* to 60*s.* on an average; but recollect that every application to art or science of this dead horse renders him of greater value; and it is for us, engaged in various ways in the arts of life, to see whether we cannot apply things that have hitherto been wasted. Five hundred horses die every week in London. The hair, you see, is worth from 8*d.* to 1*s.* per lb., and it is used for making hair-cloth, for stuffing mattresses, and making plumes, and bags for crushing seed in oil-mills. Then the hide, weighing 30 lbs., is

worth 8*s.*, which is perhaps not a great deal of money; but when you have from 300 to 500 a week dying within a radius of five miles from Charing Cross, it comes to some money. Then the skin is used for a variety of purposes; tendons you know may be made into gelatine, and glue, and jellies. I told you that you must not be particular about these jellies: when the poor old horse has drawn your carriage, served you in omnibus and cab, and died at last; even then you have not done with him, for his tendons may then serve you for your delicious jellies. Then again it is not an uncommon thing for man to eat horse-flesh. We do not eat it here knowingly, but they eat it on the continent of Europe. There is a story of a Frenchman, who thought we sold meat for almost nothing, for we sold it on skewers for a penny a skewer-full. Then there is the blood, which is carried to the prussiate of potash manufacturers. Then there are the internal tubes, which are used for the coverings of sausages; and, as I said of the jellies, we need not ask any questions about these coverings as long as they are sweet. The heart and tongue are evidently great "mysteries," for no one knows what is done with them. There is almost as much mystery about them as about the manufacture of the cloth of your coat. The heart, however, can be chopped up and mixed with sausage-meat, and the tongues may be sold for ox-tongues. On a recent occasion, when I stated this fact, a newspaper which reported my lecture added that it was all a mistake, and that the tongues were never sold for so inferior an article as ox-tongue: they were always sold as reindeer tongues. Now, passing over the fat, which is worth 3*s.* 4*d.*, I need not tell you that

horses' bones are as good as any other bones, and can be employed for the various purposes to which other bones are applied. The bones of a horse weigh about 160 lbs. and are worth 4*s.* 6*d.* per cwt. Then there are the hoofs, 6 lbs. of these, at 8*s.* to 10*s.* per cwt., which can be used for making buttons, prussiates, and snuff-boxes. I do not think that it is correct to say they are used in making glue. I think horses' hoofs are composed of the same material as hair. They are sold, it is true, to the glue-maker, but he sells them to the prussiate manufacturer. Even the poor old shoes are worth from 5*s.* to 10*s.* per cwt.; and even with regard to all these substances employed, there is nothing which cannot be used again and again.

Another source of valuable refuse is that from our fisheries :—

"Attention has frequently been directed to the substances wasted in the fisheries and returned to the sea as garbage, and to the detriment of the fisheries. The difficulty has hitherto been the collection and bringing together the refuse to one or more conveniently-situate manufactories.

"A Mr. Pettit recently patented a process for converting refuse and unedible fish into a pulpy homogeneous mass by sulphuric acid, desiccating it and mixing it with peat charcoal or some other drying material.

"Messrs. Molon and Thuneysen, the proprietors of similar works at Concarneau, on the west coast of France, and at Newfoundland, have established a fish-manure factory at Lowestoft.

"The fish are first decomposed by steam in a revolving cylindrical boiler, and the mass is then subjected to hydraulic pressure in coarse hempen mats or bags, so as to express the moisture. The hard cake of pressed fish, thrown out of the bags and broken up, is placed on slides and subjected to heat in a stove which will contain about half

a ton. It requires some hours to dry. When taken out, it is crushed or pulverized between millstones, and put into bags, holding about half a hundredweight, for sale.

"Two kinds of oil are obtained from the hydraulic pressure to which the fish is subjected, obtained by heating the expressed liquid, which facilitates the separation of the oil from the water. One quality is very pure, and sells readily; the other consists of the dregs, with a portion of the best oil. This might, by a proper apparatus, be purified, so as to render the whole available except the solid matter; and even this would be useful to soap-makers.

"A fish-manure factory is now in operation in the vicinity of Narragansett Bay, Massachusetts.

"The available offal from the Newfoundland fisheries is very large. About one million quintals of codfish are annually exported from Newfoundland. About one-half the fish—head, bones, and entrails—is thrown away as waste in the process of curing. Calculating roughly, out of every 1,000 quintals of dry cod (equal to 3,000 quintals of sound fish) there would be saved 650 tons of useful manure from cod refuse alone. Added to this there are about 600,000 seals caught every year. The bodies of these seals, which constitute their chief bulk, must give at least 50,000 tons of animal matter. In addition to these raw materials, the seas and bays around Newfoundland abound with fish of every kind, particularly the capelin, the dogfish, and others, which are peculiarly rich in oil, and can be taken in great quantities by the slightest exertion.

"In Galway very excellent azotized manures are made from the refuse of fish, bones, blood, and other substances chemically amalgamated, which contain from 32 to 50 per cent. of fixed ammoniacal salts and azotized matter.

"In the department of Finisterre, in France, a manure is made from fish. The fish undergoes a kind of cooking by steam, after which it is dried and pulverized. It requires about 500 pounds of fish to produce one cwt. of the powder, which forms an admirable manure.

"Professor Wilson, writing on the agriculture of the French Exhibition, thus speaks of fish manure:—'The fish, either the refuse of the market or otherwise, is cut into pieces and submitted to the action of high-pressure steam (four or five atmospheres) for about an

hour in suitable vessels. It is by that time sufficiently cooked, and is then ready for the presses, which expel a great proportion of the water, and leave the residue in the form of a cake. This cake is, by means of a coarse rasp or grating-machine, broken up into a sort of pulp, which is spread out in thin layers on canvass, and dried by means of warm currents of air. It is sold either in this state, or more minutely divided by means of the ordinary grinding processes. It is stated in this condition to correspond to 22 per cent. of the crude weight of the fish, and to contain from 10 to 12 per cent. of nitrogen, and from 16 to 22 per cent. of phosphate. The price was 20 francs per 100 kilogrammes (about £8 per ton), and the demand regularly increasing.'

"The value of shell-sand for agricultural purposes has long been recognized; in Cornwall it produces a marked increase in the crops of roots and corn.

"Crushed or ground shells are much used as a dry covering for paths and walks in gardens, &c.

"Burnt shells, when formed into concrete, make a most substantial and imperishable wall. Calcined shells were formerly esteemed by physicians as absorbents."

With this Lecture I finish this part of my course. I have endeavoured to bring before you very hastily some of the chemical principles in operation in the arts and manufactures. I have also endeavoured to point out to you the natural history of these things, and have done so for the purpose of impressing upon your minds the importance of studying the structure and habits of the animals used by man. I think it is the duty of a civilized community to study the history and properties of those things to which they are so much indebted for their comfort and advancement. It is just in proportion as a larger number of the population get interested in the study of the nature and properties of the objects Of the external world, that the arts and manufactures

will be advanced. Whatever may be the occupation of a man, he will be much more likely to be successful in it if he has an intelligent apprehension of the nature of the materials which he uses from day to day. If this were better understood, there would be a much greater demand for a special knowledge of the nature and properties of the substances used in our arts and manufactures than has hitherto been evinced. You know that the Government of this country is making, in connection with this institution, an effort to diffuse science-education throughout the country. But this effort will be vain unless it is supported by the public. There must be an intelligent conviction on the part of the great mass of the community that such an education is essential to our advancement and progress in civilization. Our civilization is a thing essentially different from that of the Greeks and Romans, and we ought to be able to teach our children something more than was taught by these people to their children, great as they were in their day and generation.

I think it a reproach that we in this country do not do more. In Austria, in Prussia, and Germany, and in France, through her numerous colleges, these things are taught not only to boys and girls, but to young men who are engaged in the various branches of human industry.

It is in this country alone of the civilized nations of Europe that we have no systematic teaching in the application of science to the arts of life;—it is in this country, which is in a position to take the foremost rank in these matters, that we lag behind the age.

It is not for us, who are teachers, it is not for the Government, but it is for the public to see that in the education that is given in our schools, something more than mere words and mere figures shall be taught to the rising generation.

THE END.

ROBERT HARDWICKE, PRINTER, 192, PICCADILLY, LONDON.